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'CHARTERED'

NOT LONG AGO THE WRITER WAS DISCUSSING boys' education and their careers with a housemaster at one of England's best-known schools for boys. 'Of course', the master said, as though to refute a previous suggestion that *all* boys ought to-day to receive some scientific training, 'a good many boys here go into professions such as Chartered Accountancy . . .'. Confused though this remark may be, for one cannot grant a Charter to a profession as such, it probably exemplifies many people's feelings about this particular profession as practised by members of the leading English and Scottish associations of accountants; it is a profession identified with the calibre and standing of its chartered practitioners. In fact 'Chartered Accountant' slips off the tongue as naturally as 'Civil Servant' or 'Managing Director' when one is talking of occupations. Regrettably, 'Chartered Electrical Engineer' does not. This is no question of euphony, though sometimes the more general 'Chartered Engineer' would be kinder to the ear or the eye. 'Chartered Electrical Engineer' is not at present part of the everyday vocabulary of the educated man, or even of the professional engineer himself.

There is no need here to dilate on the present ambiguity of the word 'engineer' as used by the lay public and by Fleet Street. Suffice it to say that the historical development of engineering has brought about present usage, and there is now no possibility of retaining 'engineer' to have a precise connotation such as that of 'architect' or 'physicist'. The distinctive labels to describe the callings of professional engineers are to be found in a trinity of specific terms, 'Chartered Civil Engineer', 'Chartered Mechanical Engineer' and 'Chartered Electrical Engineer'.

Since 1924 Corporate Members of The Institution have, under its Bye-laws, been allowed to describe themselves as 'Chartered Electrical Engineers', but, until a month or two ago this term—when written—had to be accompanied by the relevant abbreviated designation 'M.I.E.E.', or 'A.M.I.E.E.' Now, with a view to encouraging wider use of 'Chartered Electrical Engineer', the Council have, with the agreement of Corporate Members at the Special General Meetings held in June 1955, and in March 1956, obtained approval both for the actual description to be written into the Charter of The Institution, and for a change in Bye-law 8(*b*) to allow it to be used either with or without the abbreviated designations, at will.

The Council do indeed aim at making 'Chartered Electrical Engineer' as much a part of the natural vocabulary of the electrical industry as, say, 'Design Engineer' or 'Station Superintendent'. But they aim at more than that: 'Chartered Electrical Engineer' must find its way to the lips and pens of the public. This is not only a point of pride to the professional, and an encouragement to recruiting the brightest boys and girls, to many of whom a professional engineer may to-day appear a somewhat nebulous being; it is also an aid to the public. One of the difficulties of establishing in the minds of laymen the role played by the Chartered Engineer is that he makes few domestic non-social contacts with them. Even consulting engineers are rarely approached for domestic reasons in the way that doctors, solicitors, surveyors, etc., are consulted. Nevertheless in non-vocational discussion, e.g. on the local council or even at the golf club, it is right that others should quickly apprehend the nature of a man's profession if the need to inquire into it arises. Moreover, the public does have a little direct contact with one activity of Chartered Electrical Engineers where they may advise, for example, about wiring or rewiring a property. Recently a man to whom electricity is a firmly closed book was heard to remark, 'The electrical contractor I go to has A.M.I.E.E. after his name; I suspect he is something rather special'. Could the same man be saying in a few years' time, 'My contractor, I'm glad to say, is a Chartered Electrical Engineer . . .'? A consideration of this kind is, of course, independent of the excellent work of the National Register now to be carried on by the new National Inspection Council for Electrical Contracting: as emphasized in the Foreword to the June *Journal*, there are many electrical engineers who are not Corporate Members and who act as admirable installation engineers; the question is one of degree.

What immediate practical steps can members take to further the Council's aim? Here are some: using the term 'Chartered Electrical Engineer' on letter headings; whenever appropriate using the term as a subscription beneath a signature, e.g. in a letter to the Press; including the term after an author's name on the title-page of a book, on a report or on an article; including it on posters announcing lectures, etc.; and giving it as one's occupation when completing the many forms that beset one's life to-day. Most important of all is to use the term socially: 'Oh, haven't we met before somewhere—what's your line of country?' . . . 'I am a Chartered Electrical Engineer'. Word of mouth will establish a designation more quickly than any written example or precept.

'Chartered Engineering' may be a misnomer; but both engineering and the recruitment of professional engineers would benefit, if parents realized that behind such words lay a career which their sons and daughters could truly take up as a first-class professional activity. Only a far more vigorous application of 'Chartered Civil Engineer', 'Chartered Mechanical Engineer', and 'Chartered Electrical Engineer' in the spoken and written word can bring this about. The Council have given a clear lead over the use of 'Chartered Electrical Engineer'; now it is up to all members to follow it.

The Economics of Farming by Electricity

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By W. J. GUSCOTT, MEMBER

In this article, which is founded on the author's Address as Chairman to the South-Western Sub-Centre last year, Mr. W. J. Guscott makes a compelling economic case for greater use of electricity in farming. He writes in the light of his wide experience of rural electrification, particularly in the South-West of England. Evidence that most of his case is acceptable to farmers who are prepared to invest in the future is provided by the comments on the article that appear at the end of it. These have been written by Mr. A. Greig, who is Secretary of the Commercial Committee of the National Farmers Union. In practice, acceleration of the change from hand or tractor-driven implements to electrical machinery on farms probably depends less on economic argument than on overcoming the traditional reluctance of many farmers to invest much more than the bare minimum in re-equipping their farms. Profit in hand is frequently more attractive than greater future productivity—when the increased profit in the bush depends materially on Government price decisions and international agreements.

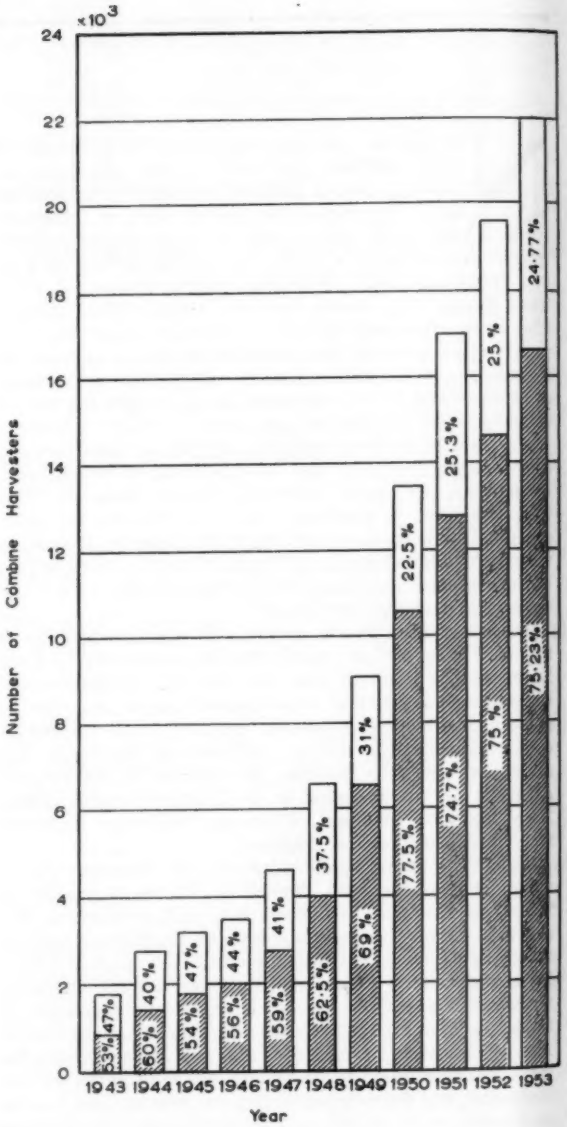
High Farming

CONDITIONS in the farming industry are changing. During the 1939–45 War and for some time afterwards, because of the loss of imported food supplies, it was essential to have more home-produced food at any cost, and it is to the lasting credit of British farmers that they responded so well to the call for increased output.

To-day, with less land—over 800 000 acres of agricultural land have been absorbed by town expansion since 1939—the return of competitive markets, and the serious drift of skilled workers from country to towns, the demand is for *high farming*, a term which implies increased economic efficiency giving bigger outputs at lower costs.

Although, to meet these new conditions, hundreds of progressive farmers are investing in greater mechanization and modernization of field work through the medium of tractors and combine harvesters (Fig. 1), far too few are turning to electricity to replace hand labour or obsolete and inefficient machines in the barn, byre and dairy. Why should this be so when, as this article sets out to show, the case for a full use of electricity on the farm is unassailable?

It seems that farmers, by and large, are not aware of two important factors: (i) electricity used for farming purposes offers a high yielding investment; and (ii) the rate of extension of rural electrification in the more remote areas is bound to slacken unless those consumers already connected make a bigger use of the supply.



1 *Increase in use of combine harvesters in Great Britain*

With bagger. With grain tank.

The total increase is 15 times in 10 years.

Economics of Rural Electrification

The national average value of electricity used on mains-connected farms (including farmhouses) during 1954–55 was £37. It is in fact little more than an Electricity Board would expect from the occupants of an all-electric five-roomed council house in a town. In the South West of England, where there is much rural territory to be developed, the average farm return is even less, at £30 per annum; and no less than 41% of the farms connected in that area consume, with their farmhouses, less than 500 kWh of electricity per quarter.

A mile of electricity mains or a single transformer can supply a hundred or more really substantial consumers in towns compared with about six or even fewer in sparsely populated rural territories. Thus, to Electricity Boards, the capital cost of electrical development per consumer is relatively higher in country districts than in the built-up areas.

Immediately rural mains extensions are erected they incur, in perpetuity, annual charges of approximately 11% of the capital cost. A little more than half of this goes to pay interest and depreciation, and the rest is absorbed by rates, way-leaves, repairs, etc., and by administration.

Electricity supplied by Boards to consumers has first to be purchased from the Central Electricity Authority at a cost in the region of two-thirds of the selling price. The gross profit, which is, therefore, about one-third of the revenue obtained through the electricity bills, is the only source from which the annual charges can be met. Clearly, if the annual value of electricity consumed on a farm is to be sufficient to meet the full yearly costs of supply (annual charges + cost of current), it must amount to 3 × 11, or 33% of the capital cost of providing the supply to the premises.

Thus, if farm supplies are to be considered on an economic basis in isolation from other forms of load development and the benefits of diversity, any sum by which farm revenue falls short of a 33% return would be a loss to the Electricity Board.

Some farms, according to the distance they are away from the supply networks, cost as much as £1000, or more, to connect to the mains. Others, of course, cost far less and a fair average capital cost to a Board like the South Western Board would be £350. Table 1 is worthy of study.

It is because of the low revenues in relation to capital cost that Boards are obliged to ask for capital contributions and minimum revenue guarantees from farmers wanting supplies.

Satisfying the Aims of Farmers and Boards

The electricity supply industry justly complains that farmers are not making a fair and proper use of electric power when it is made available.

Some farmers say that charges for electricity are too high, and this can be true when only a small number of units are consumed. Others complain that connection charges are too high, and this also has some justification when the charges are based on the length of extensions from networks sited quite fortuitously at long distances from the holding.

Boards, seeking an economic development, argue that unless the farmers install electrical equipment and use more electricity, terms and charges must remain at present levels. Farmers, in their quest for 'high farming' say that if they spend their capital on connection charges they cannot afford more for electrical plant.

Yet the aims of both can be fully satisfied. There are

Table 1. Economic Costing of Supplying a Farm with Main Electricity

(Capital cost for the mains extension = £350)

				Notes
Case 1: Revenue equal to 33% of capital cost				
Sale of electricity	£117	Cost of electricity	£78	After taking all the incomings and outgoings into account, a 33% return of capital just permits the investment to pay its way.
		Fixed charges (interest, depreciation, maintenance, etc.)	£39	
	£117		£117	
Case 2: Revenue equal to 20% of capital cost				
Sale of electricity	£70	Cost of electricity	£47	A 20% return—and most Boards are willing to extend supplies on this figure or an even lower one—would involve an average annual loss of £16 to a Board.
Loss to Board	£16	Fixed charges (interest, depreciation, maintenance, etc.)	£39	
	£86		£86	
Case 3: Revenue equal to present national average (£37)				
Sale of electricity	£37	Cost of electricity	£25	The national average return from farms in 1954–55 was £37 p.a., or 10·6% of the capital. At this revenue a Board would expect an annual loss of £27.
Loss to Board	£27	Fixed charges (interest, depreciation, maintenance, etc.)	£39	
	£64		£64	

Fixed annual charges = 11% of capital invested. Cost of energy = two-thirds of selling value at standard tariff rates.

N.B. All figures are annual ones.

few farmers to-day, within reach of connection, who by wise use of electricity could not increase farm output at reduced costs and simultaneously provide the standard of revenue required by the Boards for economic development.

Tariffs

Farming tariffs in force throughout the country are generally reasonable and attractive. In most cases they offer a final running rate of not more than 1d. per kWh. The average price paid per kilowatt-hour, of course, depends upon the use made of the supply, and if farmers use the supply only for lighting purposes, for instance, this average price will work out much higher than 1d. It is usually these consumers who complain that electricity is costly. Most Boards offer either a two-part tariff or a block tariff, and although the standing charge of the former or the number of high-priced kilowatt-hours in the latter is usually based on the capacity of the installation, the rates charged are generally lower than the rates charged for other commercial and industrial purposes in the towns. During 1954–55, for example, the average kilowatt-hour price received by Electricity Boards for farm supplies was 1·47d. compared with 1·90d. for other commercial purposes.

The farm is after all a business establishment, and a farmer who is making a wise and proper use of the supply will be the first to admit that Area Board tariffs are cheap in comparison with other forms of fuel.

Pooled Charges

It has been fairly common practice throughout the industry in the past to base capital contributions or revenue guarantees on the capital cost of the necessary extension to a farm from the nearest supply point. Farmers—particularly since nationalization of the supply industry—dislike this method and claim that it is anomalous that connection charges should depend on the purely fortuitous placing of the supply lines in relation to the situation of their premises. In this they have some cause for grievance.

The South Western Electricity Board in their new system of rural development contributions have introduced a scheme which has found favour with the farmers and their associations because it is free of this sort of anomaly. The method is to estimate the deficiency between the annual charges (11%) and the gross profit on the sale of electricity from all the farms and rural premises to be supplied within a specific time under a development schedule ranging throughout the Board's Area. After making due allowance for diversity and subvention, the minimum acceptable *total* supplementary charge for this full development plan is worked out and apportioned, on a uniform scale, between all the premises and farms to be supplied. A mixed farm of 150 acres with an eight-roomed farmhouse, or a four-roomed cottage for that matter, in one part of the Area (say the north-east corner of Somerset) will thus be asked to pay the same supplementary charges (or Rural Development Contributions as they are called) as a farm or cottage of the same size and type in the south-west tip of Cornwall.

2 *Electrically operated sterilizers are economical and facilitate clean milk production*

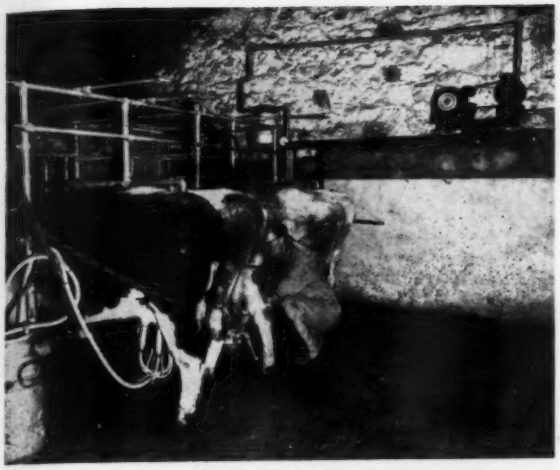
One or two other Boards are working on the principle of making uniform connection charges for farms, and the author commends the method as a valuable step towards full development of the farming load. If payment of the charge can be spread over a number of years, it is all the better since this leaves the farmer with capital which can be used to pay for electrical farm installations.

Conversion

There is hardly an indoor farm job requiring machinery or equipment that cannot be done more conveniently and efficiently by electricity than by other methods. Most conversions to this modern means of light, heat and power pay handsome dividends.

The examples in Table 2 all come from farms where the change has been made. They have been picked from a large number, particulars about which have been compiled to give practical proof of the annual saving in running costs and labour.

Such conversions, adapted to meet particular conditions, can be applied singly or collectively to any farm



3 *An electric motor driving a milking machine saves space as well as fuel*

where similar operations are carried out. The following are rough but practical balance sheets, drawn up for two farms to show the effect of the changes that could take place in them.

Farm 1

Investment. This is a mixed farm of 180 acres. The stock carried is 40 cows (average 32 in milk) and 100 head of poultry in deep litter. On the arable side about 60 acres of cereal are grown annually, 30 for feeding purposes and 30 for selling. Milking is done by a machine driven by a petrol engine. Water supply is by a pump driven by a petrol engine. Hot water and steam are produced by a coke-fired boiler. Food mixing is by hand. Corn for feeding is ground by the local miller. Lighting is by oil.

The Changes. The proposal is to change the milking machine and water pump from petrol to electric drive, to install an electric storage heater to replace the coke-fired boiler, to fix a small electrically driven hammer mill to grind corn on the premises, to provide an electric food mixer and to install electric lighting throughout the buildings including time-switch-controlled lighting in the

Table 2. Examples of Saving when Electricity is applied to Agricultural Operations

1 Agricultural operation	2 Capital cost of non-electrical equipment	3 Capital cost of electrical equipment	4 Annual running cost (non-electric)	5 Annual running cost (electric)	6 Annual saving	7 Man-hours saved annually	8 Remarks
Lighting	£10	£52	£5 13s.	£1 18s.	£3 15s.	50	Paraffin to electricity.
Machine milking ..	£35	£25	£29	£4	£25	90	Petrol engine to electric motor.
Milk cooling ..	£35	£22	£2 per week	18s. per week	22s. per week	4 per week	Summer use. Petrol engine to electric motor.
Steam raising for sterilizing (*a*)	£120	£148	£96	£45	£51	287	Coke-fuelled boiler to electrically operated steam raiser and water heater.
(*b*)	£324	£425	£273	£192	£81	90	Oil-fuelled boiler to electrically operated steam raiser and water heater.
Water supply (*a*)	—	£150	£78	£9	£69	—	Mains supply to electric pump.
(*b*)	£35	£22	£27	£11	£16	90	Petrol/t.v.o. engine to electric motor.
Food mixing ..	£32	£65	—	£2	—	730	Hand to electrical operation.
Pig food cooking ..	—	£50	£27	£23	£4	300	Solid fuel to electric boiler.
Grass drying—motive power only	£180	£125	£3 11s. per week	£3 4s. 6d. per week	6s. 6d. per week	6 per week	Diesel to electric motor.
Grinding (*a*)	—	£100	£100	£5	£95	—	Contract to small hammer mill.
(*b*)	£150	£120	£40	£7	£33	25	Tractor-driven mill to small hammer mill.
Private generation	£230	—	£113	£53	£60	195	

Table 3. The Investment Value of Farm Electrification (Farm 1)

Operation	Non-electrical: Capital cost	Maintenance	Depreciation	Running cost	Total annual charges	Electrical: Capital cost	Maintenance	Depreciation	Running cost	Total annual charges	Man-hours saved
Lighting ..	£20	£5	£4	£3·5	£10·5	£56	£0·5	£4·2	£53·6 + £35*		180
Milking ..	£35	£3	£7	£25	£35	£25	£1	£1·9			98
Water pumping	£17·5	£2·5	£3·5	£34	£40	£38	£1	£2·8			131
Water heating and steam raising ..	£120	£3	£6	£50	£65	£148	£2	£11·0			249
Grinding ..	—	—	—	£60	£60	£105	£3	£7·9			−30
Mixing.. ..	—	—	—	—	—	£75	£1	£5·6			260
Total	£292·5	£13·5	£20·5	£172·5	£206·5	£447	£8·5	£33·4	£88·6	£130·5	888

Financial saving by electrical methods = £206·5 − £130·5 = £76.
Saving in man-hours by electrical methods = 888 man-hours.

* Rural Development Contribution limited to seven years.

poultry house. Table 3 summarizes the financial effects of the changes.

In Table 3, all wiring work is included in the capital costs, and the connection charge has been included as an annually recurring amount. No allowance has been made for interest on capital expended. The reason for this is that there would be an interest component on both sides of the balance sheet, although it would be higher for the electrical equipment. On the other hand the Rural Development Contribution of £35 charged by the Electricity Board is payable for a limited period of seven years only, and the writer considers that in the long run the higher interest charges on the electrical equipment will be offset by the cessation of the Rural Development Contribution.

The introduction of electricity requires a capital investment by the farmer of £447, but two striking effects of the changes are:

(*a*) A reduction of no less than £76 in annual running costs (after making due allowance for depreciation and maintenance, etc.).
(*b*) An annual saving of 888 man-hours of labour.

The farmer would thus find himself with 'one-third of a man' to spare and an annual 'gift' of £76. It is, of course, not possible to dispense with the services of one-third or one-half of a man unless the farmer employs part-time labour; but no farmer interested in increasing the yield of his holding would wish to get rid of labour. If he is wise and looking for higher farming efficiency he will turn both the freed labour and the saved money to good account and increase production by entering into any new activity that is appropriate to the size and type of his farm. Admittedly, new activities require new capital, but the important point in this example (and in further examples described) is that the owner, having electrified, will have 'free' money, not only to pay interest on the capital, but, if he wishes, to pay off the principal in a short time. The £76 a year arising with Farm 1 will enable him to do this. Also the new activity for which the extra capital is required will provide a very high investment yield because the labour to work it is virtually free.

If the farmer employed part-time labour and was not interested in increasing the yield of his holding by taking up new activities, the labour saved could be dispensed with; the farm's net profit at the existing output would go up by about £200, which would pay off the capital cost of the electricity installation in about 2½ years.

Increased Production. On Farm 1 pig rearing is selected as the additional activity and this would require an additional capital sum of £800 for stock and equipment appropriate to the size of holding.

Table 4. The Return from an Additional Activity (Farm 1)

Capital investment		Man-hours freed for re-deployment	Net annual financial gain	Annual increase in output
Electrical equipment ..	£450	900 (saved)	£76	£1 100 = 88% of capital investment
New enterprise	£800	900 (redeployed)	£320	
Total	£1 250		say £400	

The increased production value, in pigs supplied annually to the bacon market, should be about £1 100. On present-day costing the net profit on the new venture under normal conditions and after taking all charges into account, should work out to about £320. So for a total investment of £1 250 on electricity and pig-rearing, the net profit of the establishments would go up by £320 + £76 = £396, which is nearly £8 a week. This represents incidentally an increased net return of 32%. The value of the increased output expressed as a percentage of the capital invested would be nearly 90%.

Table 5. The Investment Value of Farm Electrification (Farm 2)

Operation	Non-electrical: Capital cost	Maintenance	Depreciation	Running cost	Total annual charges	Electrical: Capital cost	Maintenance	Depreciation	Running cost	Total annual charges	Man-hours saved
Lighting (paraffin)	£10	£2	£2	£1·5	£5·5	£52	£0·5	£3·9			90
Milking (petrol engine) ..	£35	£3	£7	£26	£36	£25	£1	£1·9			90
Water supply (mains) ..	—	—	—	£22·6	£22·6	£38	£1	£3·8	£39·8 + £35*		—
Water heating and steam raising (solid fuel)	£120	£1·5	£6	£60	£67·5	£148	£2	£11			—
Root cutting ..	BY HAND					£34	£1	£2·6			243
Total	£165	£6·5	£15	£109·1	£131·6	£297	£5·5	£23·2	£74·8	£103·5	423

Financial saving by electrical methods = £131·6 − £103·5 = £28·1 (say £28)
Saving in man-hours by electrical methods = 423 man-hours.

* Rural Development Contribution limited to seven years.

Farm 2

Investment. Farm 2 is also mixed. The size is 184 acres. There are 40 cows in the milking herd and 40 other cattle out of milk or rearing and fattening; 30 acres of corn are grown for feeding purposes and the farm carries a flying flock of 120 sheep. Machine milking is done by petrol engine, and lighting on the farm is by paraffin. Water heating and steam raising are done by solid fuel, the water supply is obtained from the public mains, and root cutting is done by hand.

The Changes. The oil lighting is converted to electricity. The milking machine is driven by electrical power instead of petrol engine, and root cutting is done by electric motor instead of by hand. The water supply is changed from the mains to an electrically pumped supply from a plentiful well. Steam and hot water are produced by an electric storage heater in place of the coke boiler.

In Farm 2 the changes involve a capital investment of nearly £300 (£297 to be exact). The savings in annual running costs work out to £28 and the saving in labour to 423 man-hours.

Production and Profit. Here again to dispose of part of a farm-hand is impracticable, and so the farmer looks around for new developments. On this farm he selects deep-litter poultry, starting with 300 birds, and requiring an additional £330 of capital, for stock and housing. On a year's working, after allowing for all associated costs, he should be able to increase his annual net profit by £230. By adding the annual saving on the change to electricity the farmer could earn annually £260, or £5 a week.

The increased production arising from the new venture of poultry keeping amounts to 50000 eggs and nearly 200 table birds per annum at a market value of £950.

If the farmer could dispense with the saved labour instead of taking up poultry rearing, the changes would increase his profit by £90 per year, or if he so decided would pay off his electricity installation in 3½ years.

In both Farms 1 and 2 the change to electric working in itself increases the net profit of the farm, but the deployment of the labour saved in new activities serves

4 *The small automatic hammer mill saves labour and leaves the tractor free for field operation*

Table 6. The Return from an Additional Activity (Farm 2)

Capital investment		Man-hours freed for redeployment	Net annual financial gain	Annual increase in output
Electrical equipment ..	£300	423 (saved)	£28	£950 = 150% capital investment
New enterprise (poultry) ..	£330	423 (redeployed)	£230	
Total	£630		say £260	

a double purpose of increasing net profit still further and putting up the output of the establishment.

It might be argued that most farmers already keep poultry and pigs, but such activities can usually be extended, and in any event there are many other new interests open to a farmer with labour to spare and capital to invest.

Table 7. Investment Value of Change to Electricity

Farm	Size, acres	Capital invested in electrical equipment	Man-hours freed for re-deployment annually	Cost of electricity	Annual expenditure on electrifi-cation	Value of fuel saved
1 (as described)	180	£450	900	£54	£131	£76
2 (as described)	184	£300	420	£40	£104	£28
3	94	£90	280	£25	£55	£15
4	54	£65	290	£25	£49	−£4
5	34	£57	160	£13	£29	£10
Total	546	£962	2050	£157	£368	£125
Average	109	£192	410	£31	£74	£25

The General Case

Space does not permit the detailed description of further examples. Three other farms (all as found in the South West of England) have been treated in exactly the same way for the purpose of this article, but only the summarized results are set out in Table 7.

From Table 7 it is possible to calculate the average saving in man-hours under the various headings of expenditure. These figures, worked out on a unit basis, are given in Table 8.

By treating the profit and production side in the same way, the average value of increased net profit and increased output can be worked out for the sample of five farms. See Table 9.

The average values shown in Table 9 have been transposed into averages on unit bases. These are shown in Table 10 and provide some interesting results.

Although it must be recognized that on many small and remote farms and many hill farms the average conversion figures will not wholly apply, this does not seriously affect the case for electrifying them. There will be certain advantages and savings even on these farms, and in the farmhouse the benefits and savings can be even more pronounced than in the less remote premises.

In addition to the increase in profit and output which electricity can produce on all the farms there is another important aspect. For the extra cost of wiring the domestic premises the farmer and his wife can enjoy all the benefits and saving which a public electricity supply can provide in the farmhouse. A progressive farmer cannot overlook this amenity value. In the farmhouse electricity frees his wife from the 'hard labour' of domestic chores done by old-fashioned means, and makes her valuable services available on the business side. In the tied cottages it attracts and keeps the best type of farm worker.

Table 8. Annual Saving from Electrification

	Labour (man-hours)	Fuel (running costs)
Per £100 capital spent on electrical equipment ..	214 (value £29)	£13
Per acre of holding	3·76 (value 10s.)	4s. 6d.
Per £1 spent annually on electrification, i.e. complete annual running costs including depreciation, maintenance, etc.	5·5 (value 15s.)	6s. 6d.
Per £1 of annual electricity bill for energy	13·3 (value £1 16s.)	16s.

5 *The electrically warmed creep encourages rapid growth and prevents loss through overlying*

Table 9. Production and Profit Value of Change to Electricity

Farm	Acreage	Capital invested			Productivity and profit			
		Electricity	Farm buildings and stock	Total	Increased output	Profit from new venture	Saving on cost of fuel	Increase in farm profit
1	180	£450	£800	£1 250	£1 100	£320	£76	£396
2	184	£300	£330	£630	£950	£230	£28	£258
3	94	£90	£95	£185	£540	£225	£15	£240
4	54	£65	£300	£365	£520	£120	−£4	£116
5	34	£57	£200	£257	£360	£90	£10	£100
Total	546	£962	£1 725	£2 687	£3 470	£985	£125	£1 110
Average	109	£192	£345	£537	£694	£197	£25	£222

National Considerations

If the consumption of electricity on the 170 000 farms now enjoying a supply of electricity were increased to the level envisaged in this article and if the farms to be connected in the future make a full and proper use of their supply, the benefit to the nation and to agriculture as an industry, from increased output and reduced operation costs, would be very considerable.

Furthermore, the extra revenue to the Electricity Boards would go a long way towards making rural electrification an economic proposition, thus easing wider development.

Table 10. Increased Annual Net Profit and Output from Electrification plus a new Activity

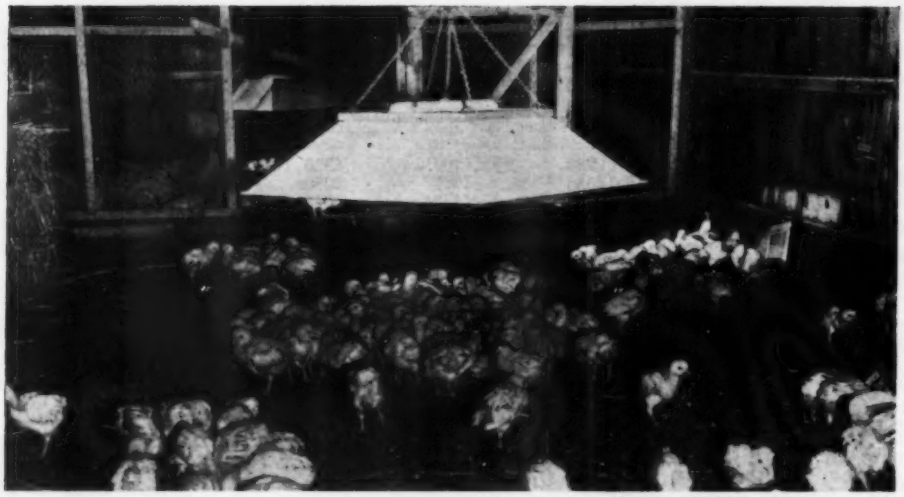
	Increased profit	Increased output
Per £100 of new capital	£41	£130
Per acre of holding	£2	£6 8s.
Per £1 spent annually on electrification	£3	£9 8s.
Per £1 spent annually on electrical energy	£7	£22

Comment by Mr. A. Greig, National Farmers Union

At the outset of his article Mr. Guscott defines his objective as being to show 'that the case for a full use of electricity on the farm is unassailable'. Apart from the fact that the N.F.U. prefers the term 'maximum economic use', I feel there is no essential difference between the N.F.U. and Mr. Guscott as to the desirability of achieving this ideal state. The N.F.U. is only too happy to place the services of its entire organization at the disposal of the Area Boards in an effort to promote this objective; indeed, many Boards have made use of these facilities with, I am sure, mutual advantage to themselves and to their farm consumers. The N.F.U. would readily admit that much still remains to be done, and it may therefore appear all the more churlish to criticize various points of detail contained in Mr. Guscott's otherwise admirable article. Nevertheless, in aggregate these small points add up to quite significant proportions and should not be allowed to pass unchallenged. Before coming to these points, however, I should like to refer to a fundamental point of policy which the N.F.U. finds it extremely difficult to accept.

Thus Mr. Guscott writes, 'If farm supplies are to be considered on an economic basis in isolation from other forms of load development and the benefits of diversity, any sum by which farm revenue falls short of a 33% return would be a loss to the Electricity Board'. Later he states that it is because of the low revenue in relation to capital cost that Boards are obliged to ask for capital contributions and minimum revenue guarantees from farmers wanting supplies. Quite frankly, the N.F.U. can see no reason whatever why farms should be considered in isolation. The alternative, of course, is a system of 'averaging out'. This principle has already been conceded so far as main distribution is concerned, for in all Areas these items are chargeable to Board funds, i.e. they are met out of the revenue from sales of electricity to all consumers. The South Western Board introduced a system some time ago whereby the costs of spur connections to rural areas are also averaged out, but the costs are recovered as lump sums from the rural consumers only. Incidentally, Mr. Guscott claims that this system has found favour with the farmers and their associations, and I wonder just how far this assertion is true.* Certainly it is an improvement on the same Board's previous system and possibly it is a genuine attempt on the Board's part to solve a difficult problem. Surely it would have been infinitely better, however, if they had gone the whole way and followed the precedent established for financing the backbone and ribs by providing

* Mr. Guscott writes: 'The farmers in the South West of England have certainly expressed themselves in favour of the South Western Board's Rural Development Contribution scheme. An increasing number of new farm connections since the scheme was introduced, at a time when the more remote rural territories are being developed, shows that the scheme is readily acceptable.'



Infra-red heaters provide the warmth necessary for chick rearing

that all capital work including the spurs was financed out of revenue from sales of electricity to all consumers? Such a system has already been adopted by several Boards and is operating well; with it farmers readily agree to accept minimum guarantees based on a reasonable assessment of maximum economic use of the supply for the type and size of holding concerned.

Let us now look at the record of farm consumption since Vesting Date. Some figures given in the 1954–55 Report of the C.E.A. are shown in the table.

Year ended 31st March	No. of farms newly connected in the year	Average annual consumption per farm (all farms)		
		kWh	Percentage increase on previous year	Percentage increase on 1949
1949	9118	3549	—	—
1950	9357	3762	6	6
1951	9940	4404	17·1	24
1952	9875	4747	7·8	33·7
1953	10584	5011	5·6	41·2
1954	12948	5204	3·9	46·9
1955	14796	5810	11·6	63·7

In assessing the merit of these figures, it must be recognized that they are in each year diluted, first by the endemically lower consumption of the new connections in that year, and secondly because the figures used for the consumption of the new connections will have been based on only one, two or three meter readings. The increase in consumption per farm since nationalization has in fact been quite spectacular, and confirms the N.F.U.'s belief that it may take several years after connection for a farm to reach its maximum economic use of electricity. After all, any businessman would be reluctant to scrap automatically machines purchased for use with other fuels and still having a useful life, just because the supply of electricity has been laid on. When such machines are due for replacement they will inevitably, however, be replaced by electrically driven types.

Mr. Guscott also makes the point that average farm consumption is no more than an Electricity Board would expect from the occupants of an all-electric five-room council house in the town. To be of any value comparisons must be of like with like, and it seems unfortunate, therefore, to compare the 'average return' from farms with the odd individual domestic consumer using much more than the average.* The real comparison should be with the average consumption per domestic consumer, which for the year 1954–55 was 1400 kWh, equivalent to a revenue of some £8·8. The corresponding figure for commercial users was 6150 kWh (£45·7) and for farm consumers was 5810 kWh (£35·7). On the basis that a farm for electricity purposes comprises the farmhouse and farm buildings, it would not seem unreasonable to expect that average farm consumption might rise to the sum of average domestic and average commercial consumption, i.e. 7550 kWh.

In conclusion, I should like to deal with a point which has not been raised by Mr. Guscott, although it is in line with his objective of encouraging maximum economic use of the supply on farms. The Area Boards have a commodity for sale, namely electricity. Their criticisms of low farm use of electricity are therefore to a large extent criticisms of their own poor salesmanship. Nevertheless it is not easy for the Boards themselves to stimulate increased consumption on farms without the fullest co-operation from the suppliers of electrical farm equipment. It is true that most Boards sell such equipment themselves, but there are many other suppliers—manufacturers, merchants and contractors. By the adoption of a stronger sales policy, they could probably do much to increase farm consumption of electricity.

* Mr. Guscott writes: 'The occupiers of all-electric five-room council houses are virtually a classified group of consumers, like farmers, and must amount to many thousands throughout the country. The case quoted in my article was not intended to represent odd individual consumers.

'If the average farm consumption reached Mr. Greig's suggested figure of 7550 kWh per annum (domestic plus business), most Boards would be well pleased. In the South West, for instance, the average consumption on farms during 1954–55 was 4975 kWh and a 50% increase to 7550 kWh would bring in an extra revenue of at least £150000 without expenditure of additional capital.

'The N.F.U. in the South West are most co-operative in every way and do everything possible to encourage farmers to make maximum economic use of the supply.'

PROVING THE LEADERS OF TO-MORROW

An Informal Account of the Administrative Staff College and its Work

F. H. BIRCH, B.SC.(ENG.), MEMBER

Mr. Birch was sent to the college in 1954 by the British Electricity Authority. He is now with the North Eastern Division of the C.E.A.

The Administrative Staff College, Henley, has in the ten years of its life gained an enviable reputation for the three-month courses which it runs for youngish men—men their employers regard as potential future leaders of the organizations they serve. This is underlined by the fact that numerous industrial and Government concerns are now willing to spare rising men of 30–40 years for three months away from their normal jobs on a course that is quite non-vocational. The course indeed aims at stretching minds and providing opportunity for testing and developing personal capabilities and not at training men for a particular end, although it presents a good measure of factual information useful to the manager, on both internal and external aspects of organizations. Much use is made of the syndicate method of instruction in which members of a class teach each other, and there are few courses of lectures as normally experienced in colleges, and no examinations.

Unfortunately, not many professional engineers have passed through the college, though more of the large electrical organizations in both the manufacturing and the supply industries are now beginning to send suitable engineers on their staffs. The Institution is actively encouraging the trend, since it regards the Henley course as admirable experience for future engineer-executives and a wise investment for any concern that wishes to make the best use of its younger top-quality staff. Mr. Noel Hall, who has been Principal of the College since its beginning and who is responsible for developing its method of work, has stated that he would be glad to have more professional engineers at the college, though a balance of professions and occupations is sought for each course.

In this article a member of The Institution who attended a course three years ago informally introduces the college. Those who feel, after reading his article, that they would like to attend a Henley course should remember that the college will not entertain individual applications—inquiries about sending staff must be made in the first place by the company or other organization concerned.

SINCE the Second World War, there has been in this country a growing sense of the need to develop and expand training in administration and management. The report on 'Education for Management' issued by the Anglo-American Council on Productivity in 1951 concludes as follows:

> We believe that American experience has shewn that productivity and education for management are closely related. The subject is of such vital importance to Britain that industry as a whole should study means for promoting educational experiments for executive development.

Since the issue of this report, universities, technical colleges, associations such as the British Institute of Management, and large industrial and commercial organizations, have started to fill this gap in our educational system by organizing a variety of management training courses.

Establishment of the Administrative Staff College

About ten years before the issue of the report already mentioned, a small group of men and women with substantial experience in industry, commerce and the public services were appreciating the need for the establishment of an independent college—a college which would bring together men and women from these three fields of activity and provide a course of studies dealing with the principles and techniques of organization and administration in civil life. In 1945 they secured the incorporation of a non-profit-making company limited by guarantee, and they launched an appeal for funds to meet the cost of opening the college and developing it through its experimental period. Early in 1946 sufficient had been promised to enable a start to be made, and a suitable building was found in Greenlands, a beautifully situated country house, near Henley-on-Thames; this was made available by Viscount Hambleden, whose family seat it formerly was.

The first and present Principal, Mr. Noel F. Hall, was appointed in August 1946, and in the following eighteen months Greenlands was adapted for the purposes of the college, staff were selected and the course of studies was prepared.

The Administrative Staff College opened in March 1948. Since that date three sessions, or courses, of twelve weeks each have been held each year. Each session since 1950 has had a membership of 60, so that about 1 500 people have passed through the college since its inception. All candidates for admission must be nominated by their employers, to whose service they will be expected to return. In choosing candidates, the college pays more attention to practical experience than to academic qualifications.

I was privileged to attend Session 19 during the first

Greenlands—the river front

This and the other illustrations in the article have been made available by Mr. Noel Hall, whose assistance is gratefully acknowledged.

three months of 1954, and in relating my experiences and impressions here I hope to throw some light on the object of the course, the method of work and the degree of success achieved.

First Impressions

After an interview by senior officers in my own organization, I was interviewed at the college with some half dozen of my colleagues. I was impressed by the beautiful setting of Greenlands, by the view of the River Thames which borders the lawns, by the well-kept and tastefully furnished house and library, and, above all, by the courteous and friendly manner in which all the candidates were received. I was rather taken aback, however, when the Principal asked me whether I snored. I soon learnt that he was concerned not lest I should disturb college assemblies but lest I should deny well-earned sleep to a fellow student, for at that time some students had to share bedrooms. This incident served to impress me with the careful attention which the Principal and college staff give to matters of detail. The candidates were told that the success of a session depends as much on contributions made by the students as on contributions made by the college staff and visiting speakers. To emphasize this students are always referred to as members of the college. It was explained that the members of a session are divided up into six syndicates, each of ten members and under the charge of a member of the college staff, and that the session membership is selected so that each syndicate will have a representative cross-section of the working life of the country and some first-hand practical experience of most of the subdivisions of the course. In this respect each syndicate is a microcosm of the session.

A Syndicate

On arrival at Greenlands at the opening of Session 19, I met the other members of my syndicate and the member of the college staff, called our 'syndicate director', who would be in charge of us. We visited our syndicate room where we were to spend a large part of the following twelve weeks and were shown a few relics left by previous syndicates. One of these was a brick which had been given to a previous member as a mark of appreciation of the many blunders he had made.

The next morning the members of each syndicate had an opportunity of taking stock of one another. In my own syndicate there were a section manager from a chemical works; a personal assistant to the chief general manager of one of the leading banks; a cost accountant from a steel combine; a Government actuary; a member of the export department of a manufacturer of textiles; an assistant to one of the docks managers of the British Transport Commission; a works departmental superintendent from a manufacturer of photographic materials; a plant engineer from a manufacturer of domestic electrical appliances; and the Director of Organization of the Israeli Army. Our syndicate director had originally taken engineering training. He then worked in the Indian Civil Service for fifteen years, after which he joined the college staff.

Distributed among the other syndicates were nationals from Australia, Holland, India and Pakistan, a citizen of the United States from Kuwait and a British national from Nigeria. In addition to a member from oversea, each syndicate had one banker, one accountant, one

One of the dormitory blocks

member from the civil or colonial services, and at least one member from the nationalized industries. The remainder were drawn from private industry and were distributed so that in each syndicate there was someone with experience of sales and marketing, production and personnel work.

The members of my own syndicate were between 30 and 41 years of age, but in other syndicates there were one or two outside this age group. The college course is designed primarily for men and women in their thirties, but the college does not apply this rule rigidly.

The Course of Studies

The course of studies and the method of work were explained to us at the outset. Eighteen subjects would be studied during the twelve-week session and members would act as syndicate chairman and secretary for each subject, the particular names being chosen beforehand by the college. The choice was made so that each member had three or four spells of office and acted as chairman and secretary at least once during the session. The eighteen subjects to be studied were as follows:

1 Comparative Administrative Structure
2 Management of the Individual
3 The Structure of Organization and Interrelation of Departments
4 Delegation, Control and Accountability
5a Works Management
b Office Services
c Management Accounting
d Consumers and Customers
e Sources of Finance
6 Trade Associations
7 Relations with Organized Labour
8 Relations with Central Government
9 Relations with Local Government
10 Use of Figures in Administration
11 Sources of Current Information
12 Adaptation to Economic Change
13 Adaptation to Technological Change
14 Imparting and Maintaining Vitality
15 Commonwealth Economic Development
16, 17 Two Biographical Studies
18 Conclusions—The Role of the Directing Authority

In addition, the Principal would give a series of four talks on the economic background to our national policies at home and oversea and the changes in our country's basic economic position. These lectures would prepare the ground for the subsequent study of subject 15.

The first subject would be a preliminary survey to which each member of Session 19 would make a contribution based on his or her personal experience. Subjects 2 to 5c inclusive would deal with administrative issues under the control of a single organization, whereas subjects 5d to 9 inclusive would be concerned with those administrative activities which require for their completion the interplay of two or more independent organizations.

Each member would study only one of the specialized subjects 5a–5e, and for this purpose he would be allocated to a fresh syndicate which would be composed largely of members having experience in the field of the subject to be studied.

Subject 10 would have the object of explaining to those without expert knowledge how to read balance sheets and other financial statements, how to apply budgetary control and standard costs, and how the control of an organization is assisted by the presentation of suitable figures at different levels of management. This subject would be dealt with by means of a series of talks given to the whole college by visiting speakers.

In studying subjects 12, 13 and 14, syndicates would examine certain administrative problems at their highest level and would need to draw on the material dealt with earlier in the course.

The Method of Work

The method of work was broadly the same for every subject, except No. 10, and it will be convenient to follow the study of two typical subjects. I will first describe the study of subject 7, Relations with Organized Labour.

Several days before the syndicates first considered this subject, their chairmen and secretaries were given copies

The syndicate chairman and secretary make a plan

of the relevant brief, time-table and reading list. They received these ahead of other members so that they could prepare schemes of work for their syndicates. After going over the papers, the chairman and secretary of my syndicate had a private meeting with the syndicate director to make sure that they understood the scope of the subject and the arrangements made for its treatment.

Our chairman and secretary then examined, with the help of the librarian, the books and pamphlets which had to be shared out among the syndicate so that work could be done effectively within the time allotted. These included three helpful papers prepared by the college's Research Department and dealing severally with Trade Union law, the organization of Trades Unions, and the State and collective bargaining.

In the syndicate organizing meeting which followed,

A chairman puts his syndicate to work

our chairman explained the work to be done and put up his proposals for carrying it out during the seven periods of 1½ hours each allotted to this subject in the college time-table. Two further periods had been reserved for visits to the syndicate by three specialists in the subject, Sir Richard Lloyd-Roberts, Mr. E. Hyman and Sir Luke Fawcett. Sir Richard Lloyd-Roberts had been for 32 years head of the industrial relations department of Imperial Chemical Industries and later head of the Personnel and Management Branch of the Ministry of Labour and National Service. Mr. Hyman was a Regional Secretary of the Transport and General Workers' Union, and Sir Luke Fawcett had been General Secretary and President of the Amalgamated Union of Building Trade Workers and for twelve years a member of the General Council of the T.U.C. Under our chairman's guidance we drew up lists of questions to put to each of the visitors, and their answers to these and to the resulting supplementary questions we found very enlightening.

The college had arranged for parties of six members, one per syndicate, to visit the Industrial Disputes Tribunal and a meeting of the Works Council of the Glacier Metal Co., and we took advantage of these arrangements. The report of our secretary on his visit to the Glacier Metal Co. showed that what he had seen had profoundly impressed him with the practical possibilities of joint consultation in furthering good relations between management and labour.

The college received an address on the subject of employers' organizations by Professor H. S. Kirkcaldy, who is Professor of Industrial Relations at Cambridge University.

Towards the end of the time allotted to the subject our secretary and chairman drew up a preliminary draft report which attempted to comply with the terms of the brief as to length and content, and to express the highest level of our thought and discussion, as distinct from the level which was common ground to us all.

After full and very frank discussion of the preliminary draft, the secretary and chairman produced the final report, which was duplicated and circulated to all members of the college. Each syndicate considered the other syndicates' reports and framed questions on them for putting at a college conference. The chairmen then met together with the member of the college staff in charge of the subject and completed the arrangements for the conference. At the conference, which was conducted by the Principal, each chairman presented the work of his syndicate for critical examination by the college as a whole in a speech lasting about ten minutes. After the conference had heard the speeches from the six chairmen, the Principal opened the discussion by selecting a question previously put up by one of the syndicates and this was discussed by the college as a whole. Not only syndicate but individual opinions found expression, and several back-benchers gave their views.

Subject 13, Adaptation to Technological Change, was handled rather differently. In this instance the membership of the syndicates was rearranged, and I found myself chairman of one of the syndicates with the member from Kuwait as secretary. The college brief invited syndicates to select an actual firm at present engaged on production, and a drastic change that had occurred in production method which would undermine the firm's business unless its management took urgent steps to adapt its affairs to the new circumstances. We chose an actual firm

Seeking information in the library, which includes an admirable selection of periodicals

A fast ball to the visiting specialist

about which we had a great deal of information and renamed it the Acorn Shoe Co. Ltd. (In what follows the letters A.S.C. are used to denote this company and not the Administrative Staff College.) The A.S.C. was engaged solely on the mass production and marketing of men's leather work-boots which were priced at £2 per pair. The drastic change in production method was the use of a plastic instead of leather, since a competitor, the Flatfoot Shoe Co. Ltd., had recently marketed a plastic work-boot (almost indistinguishable from its leather counterpart) at a price of 15s. per pair. Owing to its much lower cost, excellent appearance and wearing qualities, the plastic work-boot had a strong customer appeal which was fast gaining ground.

As invited by their brief, my syndicate set out the main facts about the A.S.C., e.g. its present aims, staff and labour situation, raw material position, output, markets, balance sheet, profit and loss account and recent profit record. We were then asked to assume that we had been instructed by the Board of the A.S.C. to submit a report not exceeding 2 500 words, setting out our recommendations on the steps which should be taken by the Board to adapt the A.S.C. to the change in circumstances. We were to distinguish between those recommendations on which the facts were sufficiently clear to justify the taking of immediate policy decisions, and those on which such decisions would have to await further clarification of the situation. Space does not permit me to state all the recommendations which my syndicate made to deal with this problem, but, briefly, we argued for a smooth change-over to the production of plastic work-boots, and application to the Industrial and Commercial Finance Corporation for a loan of £50 000 for the purpose. The change in production process would necessitate reducing the labour force to about 30% of its existing size, and this would call for immediate consultation with the Trade Union. We recommended that reduced pension benefits should be paid to the older workers who would be declared redundant.

Our study of the problem indicated that during the ensuing twelve months the A.S.C. would make a net profit almost as great as it had averaged over the previous five years. The Principal was, however, less sanguine about our firm's chance of weathering the storm.

After the chairmen had spoken to their reports before the college, the gathering was given a talk on research by Sir Charles Ellis, member of the Court of Governors of the College and at that time Scientific Member of the National Coal Board.

I was most fortunate to be included among a party of six members of Session 19 who visited the Atomic Energy Research Establishment at Harwell. After seeing some of the activities of the establishment, we spent a very interesting half-hour with Sir John Cockcroft and one of his senior assistants discussing management problems and external relations. Later in the course Sir John Cockcroft gave a talk at the college on the development of nuclear power. What he said on that occasion has since become public knowledge, but the college found it most stimulating to listen to our leading authority on nuclear research, telling us how nuclear energy would revolutionize our power stations and open up untold possibilities in raising the standard of living throughout the world.

Some idea of the college time-table may be of interest. Syndicates meet in their rooms at 9.15 a.m. and work with half an hour's break for coffee, until 12.45 p.m. Further syndicate discussions take place between 5.15 and 6.45 p.m. After dinner there is often either a college conference or a talk given by a visitor to the whole college. These proceedings generally end by 10 p.m. This time-table is followed on Saturdays as well as weekdays.

The afternoons are left free to enable members to catch up with their reading or draft reports. Alternatively they can take relaxation by shopping in Henley; playing croquet, tennis, squash or badminton; or swimming and boating on the river. There is no organized work on Sundays except in the evenings, when the college meets to listen to a visiting speaker or to syndicate chairmen presenting their reports.

The time-table includes a free week-end every three weeks. This extended from the Thursday evening until mid-morning on the following Tuesday, so that even members from Scotland can, by using sleepers or air travel, have three clear days at home. These long week-ends are appreciated by members, not only in giving them a well-earned rest but also in letting them renew acquaintance with their long-suffering families.

Boarding Arrangements

Two years ago over half the members had to share bedrooms for two or three, and a few, including myself, were accommodated in a farmhouse about half a mile away. Naturally, members could give of their best only

Each chairman reports to a critical audience

if they slept well, and this was sometimes difficult when one's room-mate was noisy or kept different hours from oneself. The college has now completed a new dormitory block, and all members are given single bedrooms.

The food was plentiful and varied, nicely served and the cooking excellent. The domestic superintendent expected every member to put on weight during the course, and, despite the recreational facilities available, was seldom disappointed. The arrangements for mail, laundry, cleaning and repair of clothes and for dealing with other personal wants were very satisfactory. Members' bedrooms were dusted and tidied each day, and altogether we gained the impression of being very well looked after. There is a bar on the premises managed by the College Club; the members of each session are fully represented on the committee.

Conclusions

How did I benefit from the course? I found it of great value in providing a yardstick with which to measure my own opinions, experience, capacity and ability. The intellectual standard was high and stimulating, and I appreciated the opportunity of free and frank interchange of ideas on a wide variety of subjects. I was glad to discuss, in such an atmosphere, the major problems confronting the industrial and social life of this country at that time. Also, I found it extremely refreshing mentally to have to grapple with subjects which had hitherto lain outside my own sphere.

The discussions in syndicate and with the whole college showed me how, by good will and patience, common agreement can often be reached by people of widely differing viewpoints.

In my view the value of the course was much enhanced by the use of the syndicate method of study, instead of the more conventional method involving lectures to large classes. The far greater opportunity for discussion offered by the syndicate method is clearly an important advantage where, as at the college, the subjects studied are outside the field of exact science, and students possess a considerable fund of experience bearing on the syllabus.

I was greatly impressed by the high quality of the work of the college staff, the careful attention which was given to every detail of the curriculum and the boarding arrangements, and the trouble taken by the Principal to make personal contact with every individual member, both during and at the close of the course. I felt that the college was always ready to listen to constructive criticism and was continually searching for ways and means of improving the course.

On leaving the college, most members join the Greenlands Association, which helps them to keep in touch with other local members through talks, discussions, visits and social functions. Our North Eastern Branch can generally muster about twenty at such gatherings.

It should be mentioned that colleges run on similar lines have within the last few years been set up in Australia, Italy and Holland. Since the college opened there have been nearly fifty members from other European countries, over thirty from the American continent, nearly seventy from Asia, nearly thirty from Africa and over twenty from Australasia.

To sum up, the opportunity of getting to know a group of sixty people with a very wide variety of experience and background, and of engaging with them in the course of study provided at the Administrative Staff College, cannot but broaden a man's outlook; enable him to test his previously conceived ideas; and give him an added confidence in tackling the difficult administrative problems that arise in the present phase of this country's industrial revolution.

Croquet is popular at Greenlands, and this scene shows a game in progress with the entrance front of the house as a background

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MICROWAVE VALVES

With such a rapidly expanding subject as microwave electronics, components are constantly being developed and revolutionized, unsuspected uses being found for some, and better devices replacing others. Dr. Thomson, who is Director of Research at the British Scientific Instrument Research Association, reviews the microwave valves of to-day and indicates the trend of development. A few of the illustrations appearing here are taken from Dr. Thomson's lecture on 'Developments in Thermionic Devices since 1939', which is included in The Institution's publication 'Thermionic Devices 1904–1954'.

J. THOMSON, M.A., PH.D., D.SC., F.INST.P., MEMBER

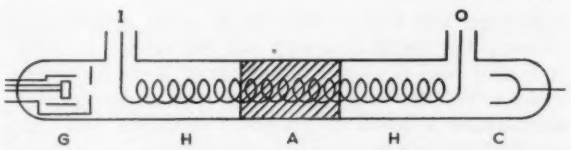
THE branch of electrical engineering concerned with radiocommunication, radar, computation and control has expanded in proportion to the advances made in electronic valves, in much the same way as aeronautical engineering has advanced according to the development of new aero engines. These valves, the engines of the electronic machines, have improved in many ways over the past decade, but perhaps the most interesting and important advances have been made in the microwave region of the spectrum. Although the development of new valves has always been aimed at improving existing electronic machines, it has turned out that the new devices allow engineers to do things which were previously impossible, and the final result of microwave valve research may well be felt in fields quite different from those usually associated with magnetrons, klystrons and travelling-wave tubes.

To a large extent microwave electronics has overtaken medium-wave electronics. Valves are now available for all purposes in the microwave region of the spectrum, including small signal amplifiers, frequency convertors, high-gain medium-power amplifiers, oscillators, high-power amplifiers, fast cathode-ray tubes and switches. The superiority of some of these devices over their older medium-wave counterparts is attributable to the following causes. First, amplifiers suitable for use over a large frequency range (broad-band amplifiers) are more easily made at microwavelengths. Secondly, only at these ultra-high frequencies can oscillators be made in which the tuning is entirely electronic over a wide range; voltage tuning, as it is called, is a feature of devices which employ *velocity modulation* of the electron current. Thirdly, in many cases it is necessary at these frequencies to integrate the valve and its circuit. Indeed most microwave electronic devices are complete units—amplifiers or oscillators or whatever is wanted—and only need to be connected together by waveguide or coaxial cable to form a complete microwave machine. The system engineer's task is therefore simplified, although it is at the expense of his colleague making the valve.

Travelling-Wave Tubes

One of the most important valves to-day is the travelling-wave tube. The principle of this is illustrated in Fig. 1.

The tube contains an electron gun G at one end, a wire helix or other slow-wave structure H, an inlet I for inserting the signal to be amplified, an outlet O for taking out the signal, and a collector C for the electron beam. The electrons from the gun, having been accelerated to the appropriate speed, are kept in alignment by a magnetic field produced by an electromagnet or by slabs of a ferrite material surrounding the tube. By the interaction of the electrons with the electromagnetic field of the helix, the small signal inserted at I is gradually amplified, and emerges at O with its power increased some hundredfold. In order to prevent power being fed back from the output to the input, there is an attenuator A across a section of the tube. This is just sufficient to prevent regeneration.



1 *The essential parts of a travelling-wave amplifier*

The important parameters of travelling-wave tubes are:

(*a*) the power gain, which is self-explanatory;

(*b*) the bandwidth, which defines the frequency range over which signals can be amplified;

(*c*) the noise factor of the tube, which may be roughly defined as the ratio of the noise power generated by the valve to the thermal noise associated with the circuit; and

(*d*) the cross-modulation factor of the device, which defines the degree of crosstalk introduced during amplification.

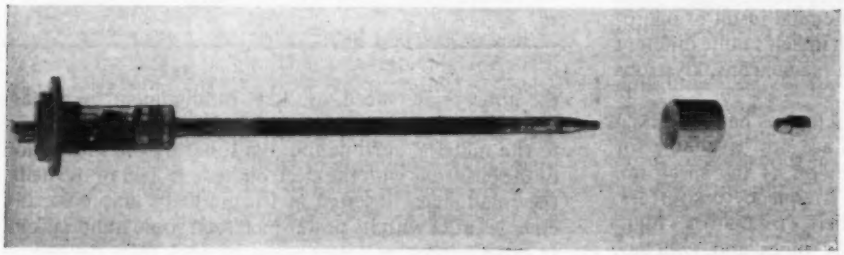
The tube is used for the amplification of microwave signals. It was invented by Kompfner in 1942, and

development, initially rather slow, is now becoming much more rapid as tubes find useful applications. Low-noise tubes are available from manufacturers in this country to amplify the power of signals by 1000 from a level only ten times that of the unavoidable thermal noise in the system. Such an amplifier will deal with signals spread over a frequency range of almost an octave. To give a specific example, a valve is available operating at a centre frequency of 4 Gc/s,* with a bandwidth of 2 Gc/s, a noise factor of about 8 dB and a power amplification of 15 dB. When travelling-wave tubes are used to amplify signals which are well above the thermal noise level, the precautions against noisiness in the tube are not necessary and a higher gain can be achieved. Such tubes are used along with low-noise tubes in Post Office telephone repeaters and in television microwave links. They bring the output signal to a level of the order of a few watts. Fig. 2 shows a typical travelling-wave tube of this type for use at a frequency of about 4 Gc/s.

Travelling-wave tubes can also be employed as power amplifiers, and indeed there is no exact dividing line between the signal amplifier and the power amplifier. A British valve providing an output of 30 watts continuously at 3 Gc/s is available, but for most communication applications a power of 5 watts is adequate, and tubes yielding this power at various frequencies are available from several British sources. The travelling-wave tube is unlikely to be used where very high mean output powers are required. The existence of the attenuator causes the dissipation of a certain power in the valve, and attempts made to employ a reactive attenuator have not so far been very successful.

The importance of the travelling-wave amplifier lies in the fact that it is an almost aperiodic structure and therefore has a very wide bandwidth. This property may be put to even better use in the future, for if it is required to amplify signals having greatly varying frequencies or having a waveform containing many high harmonics, the travelling-wave tube may be the best means available. In this case it may even be necessary to use the signal which is to be amplified to modulate a microwave carrier and then to employ demodulation after amplification. In theory, at least, many of the wide-band amplifiers used to-day are technically obsolescent by reason of the emergence of the travelling-wave tube. It will, however, be some time before the latter can be an economic competitor in domestic radio and television sets.

* 1 Gc/s = 1 000 Mc/s.



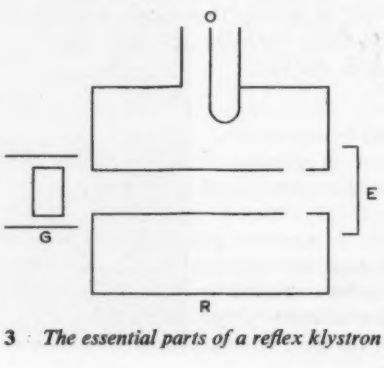
2 *Production version of a power amplifier*

The gun structure is on the left; the attenuation is indicated by the darkening in the middle of the tube; on the right is the detachable perforated cylinder for air-cooling the collector.

Oscillators

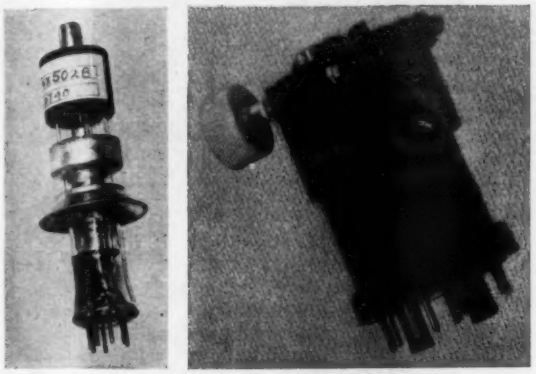
Microwave oscillators can be divided into two categories according to their power output. They can also be classified as klystrons, backward-wave oscillators and magnetrons. For the purpose of this review the attributes of each type of valve will be considered in relation to the others. The 'conventional' low-power microwave oscillator is the reflex klystron. This is a valve which gives a power output of 1–100 mW at a frequency which can be controlled to a certain extent by the voltage applied to one of its electrodes, and which may be mechanically tuned over a fairly wide range of frequencies. There are several first-class low-power oscillators of this type on the market at the moment. They are rugged and reliable and for general purposes quite satisfactory. The more modern type of low-power oscillator is a variant of the travelling-wave tube known as the backward-wave oscillator, in which the noise energy at a particular frequency is amplified while being propagated in the direction opposite to that of the beam. The backward-wave oscillator needs no mechanical tuning. Its frequency is almost entirely determined by the voltage at which it operates and so it is tuned electronically. Valves are just becoming available in this country, and are already available from France, giving outputs of the order of 10 mW minimum and covering almost an octave by voltage tuning. Such valves can be made at any centre frequency between 1 and 40 Gc/s.

The principle of the reflex klystron is fairly widely



3 *The essential parts of a reflex klystron*

known, and only a word will be said about it. Fig. 3 is a diagram of a cross-section of a valve. The electron resonator R is tuned to frequency *f*. The noise voltage at this frequency, enhanced by the resonator, velocity-modulates the electron beam. The modulated beam is reflected by the electrode E, and returns to the resonator space-modulated, or 'bunched'. These bunches excite the resonator at frequency *f*, producing stronger modulation of the beam. There is, therefore, electronic feedback in the system, and the valve settles down to give a power output determined by the losses in the valve and the efficiency of the interaction between the beam and the resonator. Fig. 4 shows two typical modern low-power oscillators. Both are reflex klystrons, but the valve in Fig. 4(*a*) is detached from the resonator, which is an integral part of the valve of Fig. 4(*b*).



a b

4 *Typical modern low-power klystron oscillators*

a The gun structure is at the bottom and the valve base is conventional. The two middle electrodes which fit into the resonator are of copper, the glass envelope being sealed to each surface of the two copper discs in annular form. The reflector is at the top.

b The valve base is conventional. The glass envelope is almost totally enclosed in a metal body, part of which is the resonator. The power is taken from the waveguide connection, the flange of which can be seen at the back. Mechanical tuning is performed by the knob at the top left, while the reflector connection is at top centre.

The principle of the backward-wave oscillator can be followed from Fig. 1 if we imagine that the input I is the output, and that the output line O is eliminated entirely. Also, the attenuation must be drastically reduced. In all oscillators we imagine that a noise voltage at the appropriate frequency *f* is amplified by the tube, and that a small part of the amplified signal is fed back to maintain the oscillation. In the backward-wave oscillator the *forward wave* travels with the beam and modulates it, but the energy transfer from the beam to the travelling wave occurs only at a selected frequency (depending upon the voltage) and only in the *backward wave*, which travels against the beam. The forward wave affords the necessary feedback to maintain the oscillation; while the backward wave is amplified by its interaction with the beam if its frequency is in a certain relationship to the beam voltage. Since the interaction circuit of the valve itself (often a helix or a set of spaced copper fingers) has a very wide bandwidth, the beam voltage determines the frequency over an equally wide band, and this is the most valuable property of the backward-wave oscillator.

For use at higher powers (from 1 watt upwards), two valves are available: the direct klystron oscillator and the magnetron. In the direct klystron oscillator the noise signal appears in the first of two cavities which are tuned to the same frequency. In the first cavity it modulates the electron beam at a particular frequency, and this velocity modulation produces a large signal in the second cavity. A fraction of this large signal is then fed back electromagnetically in the proper phase to the first cavity to maintain the oscillator, while the larger fraction is available as the oscillator output. Klystron oscillators giving powers of the order of 100 watts at frequencies up to 10 Gc/s are now commonplace. Their applications have yet to be explored in detail, but in communication systems and in some television links they are used with effect. As will be seen later, the modern tendency is away from the high-power oscillator. Engineers are tending to bring microwave systems into line with their lower-frequency counterparts, in which there is no place for the high-power oscillator.

There is one exception to this, the high-power multi-cavity magnetron, which has found very large use in radar systems, will continue to be used for many years in a certain number of these, and may well find many other uses as a generator of high powers for industrial use where the spectrum of the oscillation is comparatively unimportant. With the magnetron, peak powers of the order of 10 MW and mean powers of the order of 10 kW are obtainable at frequencies of the order of 2 Gc/s.

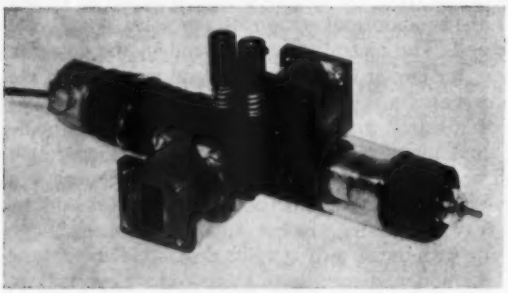
One of the most curious aspects of magnetron design is that the fundamental action of the valve is still not understood. The reason is to be found in the complex nature of the circuit which is an integral part of it. If the multi-resonator magnetron could be regarded simply as a set of identical resonators distributed symmetrically about a cylindrical cathode of infinite length, there might at least be a chance of deriving a satisfactory theory, but the presence of end spaces beyond the resonators and the certainty of asymmetry, however small, make the problem of dealing with the already intractable space-charge cloud in the interaction space almost impossible. Nevertheless, the future of the magnetron as a means of high-frequency heating could be very bright. It will probably tend to be less used in radio.

Power Amplifiers

It is only within the last few years that good power amplifiers have become available in the microwave region. As mentioned in an earlier paragraph, the travelling-wave tube amplifier is limited in its power output by the attenuation which must be an integral part of the valve. The klystron amplifier is free from this disadvantage, but in its earlier form it was such a narrow-

band device that from the point of view of the conventional radio engineer it could not be regarded as a satisfactory component. It has recently been shown, however, that klystron amplifiers can be built for high power outputs with bandwidths of the order of a few per cent of their centre frequency, and this has altered considerably the outlook for high-power transmitters. Klystrons have been made having gains of the order of 70 dB associated with bandwidths of the order of 5 Mc/s at a centre frequency of 10 000 Mc/s. Such a valve may have its resonators so staggered in frequency as to give a gain of 40 dB with a bandwidth of the order of 30 Mc/s. At lower frequencies bandwidths of the order of 100 Mc/s have been achieved with about the same associated gains (40 dB). A year or so ago it was imagined that these performances could be achieved only where the peak power was very high (of the order of megawatts) and the operating voltage was of the order of 100 kV. It is now known that this is not so, and valves can be made using many resonators, the latter being preset in frequency so that good bandwidths and gains can be achieved at moderate voltages. Much of the earlier klystron theory, which showed the way to these modern valves, has destroyed itself in the process. There is room here for much theoretical investigation to optimize the various valve parameters.

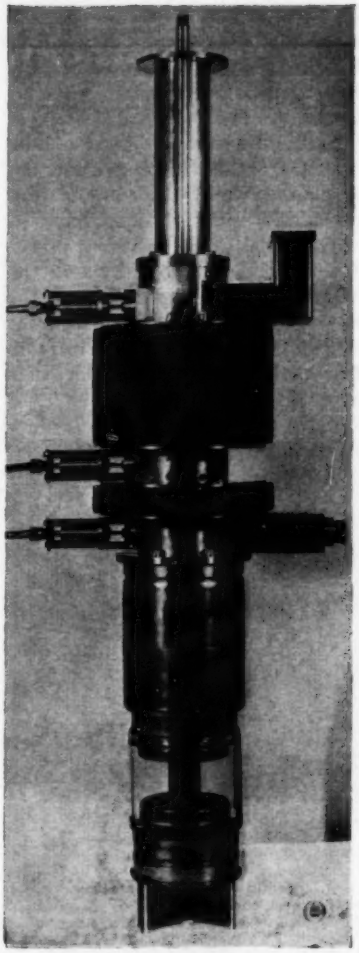
In the meantime klystron amplifiers which give powers of the order of 1 kW continuously at microwavelengths, with gains of the order of 10 dB, are commercially available, and these may be regarded as the forerunners of the valves of higher merit referred to above. Microwave engineers can confidently look forward to having, in the near future, amplifiers much superior to those now in use. Fig. 5 shows a valve for use at 10 000 Mc/s giving a c.w. output of 1 kW.



5 *Klystron amplifier for 3 cm operation*

The gun connections are on the right, the two resonators are in the middle, and the water-cooled collector is on the left. The input and output waveguides are clearly seen on either side of the resonators. The tuning plungers are at the top, side by side, being mounted on springs to avoid vibration modulation.

Looking a little more into the future, the valve designer is not yet sure what form the power amplifier will eventually take at frequencies above 1 Gc/s. Although both the travelling-wave tube and the klystron have given very satisfactory performance, it is possible that a valve which



6 *Klystron amplifier for 10 cm operation*

The gun structure is at the bottom and the water-cooled collector at the top. The position of the input resonator is indicated by the input coupler on the right and the tuning mechanism on the left. The second resonator is close to the input. Its tuner can also be seen. The output resonator, nearest the top, bears the output guide (which has a right angle bend in it). The magnetic coils can be seen surrounding the resonators. The magnetic field of these coils keeps the electrons together in their journey from the cathode to the collector.

is a compromise between the two may well form a major advance. The dilemma may be put roughly in the following manner. The objection to the travelling-wave tube amplifier is that it must contain attenuation as an integral part of it, in order to avoid regeneration. The objection to the klystron amplifier is that, as originally conceived, it was a narrow-band device and as such most objectionable as an equipment component. A large number of resonators interconnecting with a single electron stream and suitably staggered in frequency is a step in the right direction, but it may not be the final answer. Fig. 6 shows a photograph of a three-resonator

klystron giving an output of several megawatts peak power at a frequency of 3 Gc/s. Its gain is 30 dB for a bandwidth of a few megacycles per second.

Frequency Convertors

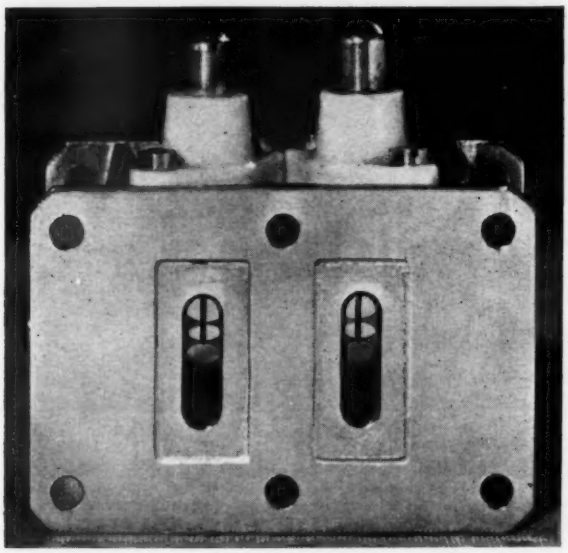
An essential element in microwave radio is a device with a very low noise factor capable of converting a modulated microwave oscillation to a modulated oscillation at a much lower frequency. The valve used at present for this purpose is a silicon rectifier comprising a crystal of silicon making point contact with a tungsten wire. This is one of the microwave devices whose free development has been inhibited by the demand for mixers for radar sets. A frequency convertor should have the maximum possible conversion efficiency and the lowest possible noise factor, but in a radar set it must also be very resistant to electrical shocks from the transmitter. It is likely that in the future radar receivers will incorporate low-noise travelling-wave amplifiers between the aerial and the frequency convertor, in which case the crystal itself will be protected from electrical shock and more attention can be given to improving its other electrical characteristics. Moreover, the use of good single-crystal silicon which is now available in this country may well improve the sensitivity of the device; it will certainly make for greater uniformity in the finished article. The engineer of the future, therefore, looks forward to better frequency conversion from solid-state devices, of which the first will be an improved point-contact silicon rectifier. What the future holds in store in the way of microwave transistors it is impossible to say at this juncture.

7 *Transmit/receive switches*

(*left*) A tunable transmit/receive cell which fits into a circular waveguide. The tuner is at the bottom and the d.c. connection at the top. One glass window of the cell can be seen inside the waveguide connection.

(*right*) This cell is for use in a balanced system. It consists of two resonators which are twins. Each covers 8·5–10 Gc/s. The two have a common gas filling to ensure that they will vary in step, if at all.

Without speculating on new developments, it is worth while calling attention to the present performance of microwave convertors. A noise factor of 6 dB can be achieved in practice at a frequency of 2000 Mc/s, rising to 8 dB at 4000 Mc/s. It is only a few years since the noise factor of the best receiver at 200 Mc/s exceeded 10 dB, and so progress has been made. Much of this progress has been on the side of better circuit design. The advent of the so-called 'preplumbed' convertor—a circuit expressly designed to operate over a given frequency band, using standard crystal valves, without tuning or adjustment—and the growing utilization of the 'balanced' convertor—



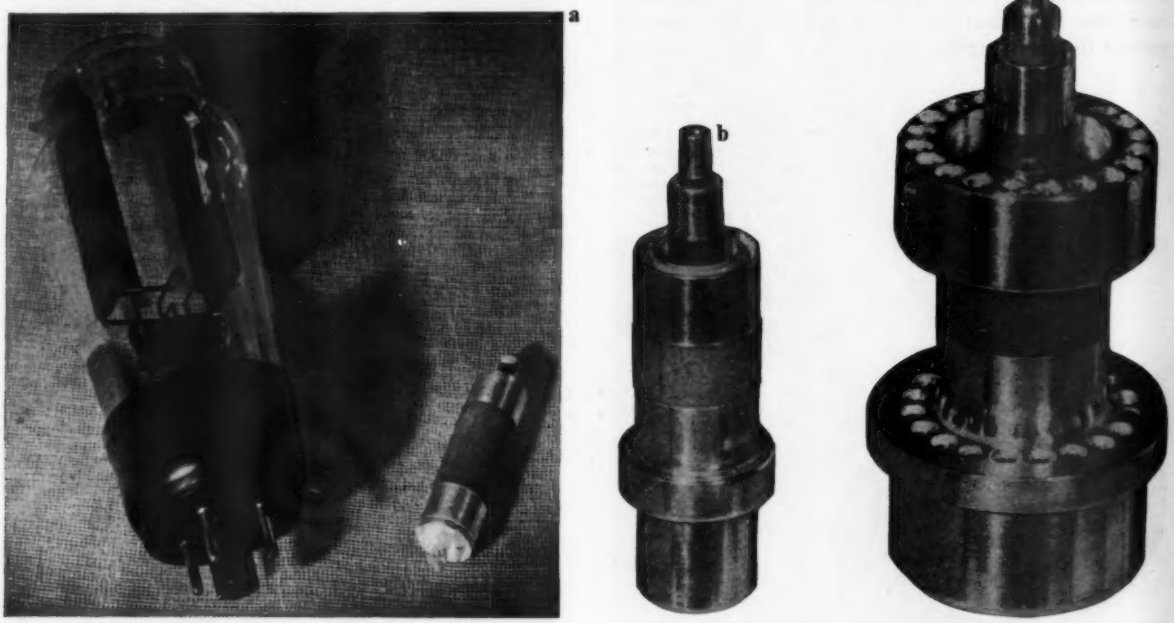
where noise is reduced to a minimum—have done much to improve the performance.

Duplexers

In many microwave communication and radar systems it is necessary to use the same aerial in transmission and reception. Quite complex systems have been evolved over the years under the generic title of *duplexers* to perform this function. Starting from a simple transmit/receive switch, which was essentially a chamber resonant at the carrier frequency and containing a small amount of gas, duplexers have become much more complex in recent years. There has been a tendency to separate the various functions of a duplexer and to design components to perform each of these functions. At the same time, much thought has been given to broad-band duplexing devices so that transmitter and receiver frequencies can be moved about within certain limits with ease. Excellent trans-

mit/receive switches and ancillary devices are now available commercially in this country, typical cells for use at 10 Gc/s being shown in Fig. 7 (p. 665).

With the emergence of new ferrite materials exhibiting gyrator effects, some of the duties of the gas-filled transmit/receive cell have been passed over to a piece of waveguide containing the new material. Extensive research on microwave ferrite devices is in progress, and already devices suitable for use in marine radar equipment are available.



8 *Ceramic valves*

a The small cylindrical valve on the right is a diode giving 200 mA d.c. at 600 volts d.c. The valve on the left is its glass-envelope counterpart. The ceramic valve has its heater and cathode connections at the top and its sealing-off pip at the bottom.

b A triode which may be used as a power amplifier or oscillator, giving 30 watts c.w. or 15 kW peak. Its upper frequency limit is about 1 Gc/s. It may also be used as a series stabilizer at 20-watt output, carrying 200 mA d.c.

c A triode for use as an oscillator or amplifier at outputs up to 100 watts c.w. or 50 kW peak at 1 Gc/s. The air cooling of the electrodes is shown.

Fast Cathode-Ray Tubes

Another electronic device which is of the utmost importance in microwave engineering is the cathode-ray tube which will produce a visible trace for frequencies of the order of 10 Gc/s. Several tubes now exist which can be employed to examine transients contained within a time interval of the order of 10^{-10} sec. The theoretical limit in special demountable equipment appears to be somewhere in the neighbourhood of 10^{-14} sec. When one is reminded that the half-life of an excited atom may be as large as 10^{-8} of a second, this new display technique is put in the proper perspective. Needless to say, this fast writing speed is not achieved with voltages of the same order of magnitude as those used at ordinary frequencies, but the instrument is quite practical for most purposes.

The engineer may therefore rely on the cathode-ray tube to display his waveforms at microwavelengths just as he does at lower frequencies. The microwave communication link can now be continuously monitored if it is so desired.

Background Research

The background to all these advances in microwave electronic devices is the continuing study of and improvement in materials. Better ceramics, copper, and tungsten are now available, making many of the technological problems associated with valve design much easier. Also, as mentioned above, the work in progress on single-crystal silicon for use in rectifiers and transistors will have repercussions in the microwave field. It may in justice be said that often the biggest obstacles to advances are not in design but in the properties of materials. Many of these difficulties in microwave engineering have now been overcome.

The importance of new and improved materials cannot be overemphasized, an interesting example being the vacuum-tight low-loss ceramic now used in the manufacture of many valves as part of the valve envelope. From time to time different scientists have adduced what appeared to them good reasons for replacing the glass in microwave valves by a ceramic. Despite differences of

opinion this would have been given an extensive trial long ago had it not been for the difficulties experienced in obtaining the right quality of ceramic to reasonably close tolerances in its constitution. Now that ceramic valves have been made in fairly large numbers it has emerged that the principal advantage in the use of the new material had not been imagined even by those engineers who were its strongest supporters. Valves using a high-temperature ceramic, made in the correct fashion, give a much improved cathode emission which may be employed either to improve the electrical characteristics of the device or to increase its life and reliability. Although such ceramic valves were originally developed for use in the microwave region of the spectrum, it is likely that their use will spread to other frequencies in the near future. Fig. 8 shows a few ceramic valves now available from British sources.

Conclusions

Microwaves are associated in the minds of most electrical engineers with radar, radio beacons and point-to-point communication links. For these purposes the new generation of microwave valves were designed, and they appear to be very satisfactory. Microwave radio can now take its place with medium-wave radio as an exact science in which all the variables are under control. This has special significance in connection with communication by tropospheric scatter and the transmission and reception of colour television.

But there is another aspect of microwave engineering which may come to have even greater importance. By making the proper use of the devices described in this article, engineers can create electronic machines capable of performances hitherto regarded as impossible. For industrial heating, for rapid computation, and for high-speed control of processes the instruments are to hand.

The table summarizes the devices available on the British market at the moment with some general comments regarding their performance. It should not be regarded as exhaustive, but as an indication of general types.

Acknowledgments

The photographs of valves have been included with the permission of the following firms: Standard Telephones and Cables, Ltd., Electric and Musical Instruments, Ltd., English Electric Valve Co. Ltd., Metropolitan-Vickers Electrical Co. Ltd., and Ferranti Ltd. I have to thank the Admiralty for the permission to publish; the views expressed are my own responsibility.

Microwave Valves at Present Available

Type of valve	Frequency range, Gc/s	Power output, watts	Efficiency, %	Gain, dB	Noise factor, dB
Magnetrons	1–3	2×10^6 peak	50	—	—
	3–10	1×10^6 peak	40	—	—
	10–30	1×10^5 peak	30	—	—
	30–80	5×10^4 peak	20	—	—
Klystron power amplifiers	1–3	1×10^4 mean	30*	30	—
	3–10	2×10^3 mean	20	30	—
Klystron power oscillators	1–3	1×10^4 mean	25	—	—
	3–10	2×10^3 mean	20	—	—
	10–40	50 mean	10	—	—
Travelling-wave power amplifiers	1–3	50† mean	10	20§	—
	3–10	5 mean	10	20§	—
Klystron low-power oscillators	1–3	1 mean	<5	—	—
	3–10	0·1 mean	<3	—	—
	10–40	0·02 mean	<1	—	—
Backward-wave oscillators	3–10	0·1‡ mean	<3	—	—
	10–60	0·01 mean	<1	—	—
Travelling-wave low-noise amplifiers	1–3	—	—	40§	6–8
	3–10	—	—	30§	8–12
Crystal frequency convertors	1–3	—	—	—	6–8
	3–10	—	—	—	8–10
	10–30	—	—	—	10–15

* Klystron amplifiers have been made giving 50% efficiency but they are not yet available.
† This figure can be exceeded by special design.
‡ Higher figures can be obtained. Those quoted relate to the normal use of the devices.
§ The gain is a function of the bandwidth. The figures quoted are for a bandwidth of about half an octave.

'Radio Astronomy and the Jodrell Bank Telescope'

621.396.99:523.164

A Summary of the 1956 Kelvin Lecture

On the 26th April this year Professor A. C. B. Lovell, O.B.E., M.Sc., Ph.D., F.R.S., gave the Forty-Seventh Kelvin Lecture to a crowded meeting of The Institution. His subject was 'Radio Astronomy and the Jodrell Bank Telescope', a field with which he has been associated since 1945, when he was appointed a Lecturer in Physics at the University of Manchester. As will be known to many readers, Professor Lovell is now Professor of Radio Astronomy at Manchester University, and Director of the Jodrell Bank Experimental Station, Cheshire. The summary given here outlines some of the more interesting facts and theories given in the Kelvin Lecture; for the complete text, readers are referred to this month's issue of the Proceedings, Part B.

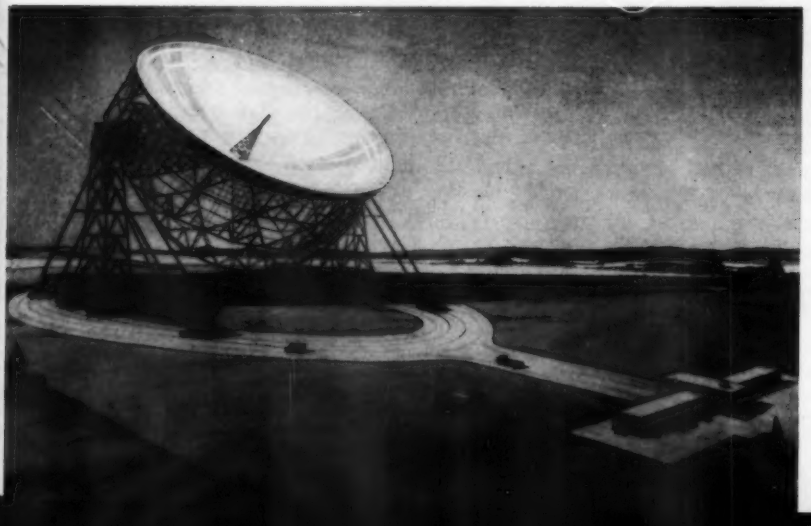
ASTRONOMERS were slow to act on the discovery by K. G. Jansky in 1932 that extra-terrestrial radio waves were reaching the earth. But the vast development of radio and radar in the war stimulated interest in radio astronomy, and by 1950 a large transit radio telescope was operating at Jodrell Bank; this showed that both extragalactic nebulae as well as sources in the Milky Way emitted radio waves. At this time serious consideration was being given to the construction of a fully steerable telescope of similar aperture, and by 1952 difficulties of the finance and engineering of such a project had been overcome. Work on a 250 ft-aperture telescope for Jodrell Bank started in the autumn of that year, and it is expected that preliminary tests will begin early in 1957.

The reflector of the telescope (Fig. 1) is a solid welded-steel paraboloid having its focus in the plane of the aperture, with the primary-feed aerial carried on a central tower along the axis of the paraboloid. Fig. 2 shows the calculated power gain and beamwidth; at the shorter wavelengths bowl distortion will affect the power gain significantly, although the shape should not vary by more than ± 1 inch under operational conditions. The telescope, which is not equatorially mounted, is controlled in elevation and azimuth by electric motors in a Ward Leonard system. A specially designed control system using Magslip resolvers and servos allows the altitude-azimuth motion of the instrument to be converted into sidereal motion; it also allows the telescope to scan automatically or to follow the complicated movement of the sun, moon and planets.

The origin of galactic radio emissions is uncertain. Although their intensity is greatest in the direction of apparent greatest density of stars (i.e. towards the galactic centre) radio emission has not been detected as coming from any star (except the sun), and it is possible that its true source is interstellar gas. The presence of the background continuum of radiation cannot be explained by the known localized sources, whether extragalactic or in the Milky Way. There are many theories about the observed distribution of radio intensity and much work will be done on this problem with the new telescope at Jodrell Bank.

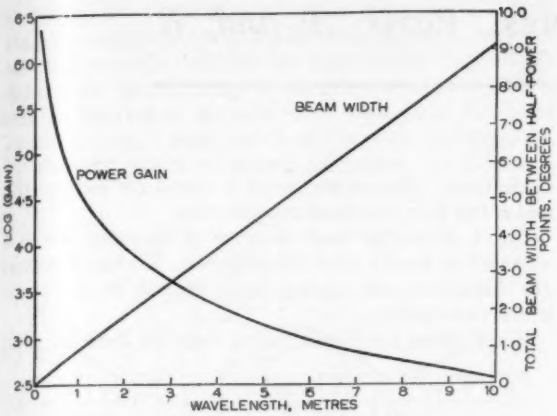
Some 2 500 localized sources of radio emission have so far been found in space from surveys in England and Australia, and of these it seems likely that about 20 are part of our own Galaxy. A few of these sources are associated with the remnants of supernovae, the most notable being the Crab nebula, which is the expanding gaseous shell of the supernova of A.D. 1054. This source is the third most intense in the sky, its distance being about 4 000 light-years; it is probably responsible also for the generation of cosmic rays. The most intense source lies in Cassiopeia, its angular extent being about 4′, but it is only very faint visually, consisting of a nebulosity whose gaseous filaments are moving very rapidly. The reason why it is so powerful a radio emitter is not clear. The composition of all the galactic radio sources appears to include faint diffuse gas; whether they are all really of the same character is not known, but efforts to link them with rare classes of galactic objects such as novae and globular clusters have been unsuccessful.

Turning to the extragalactic sources, we find that they are distributed isotropically and that a few of them are identifiable as telescopic nebulae. The great Andromeda nebula was established as a radio emitter in 1950, by means of the transit telescope at Jodrell Bank. Soon afterwards the second strongest source in the sky was found to lie in Cygnus, where two galaxies have collided at a distance from the earth of 200 million light-years. There are also a large number of unidentified extragalactic sources. The spatial distribution of these radio stars, which are not associated with visual telescopic objects, has been investigated at Cambridge by plotting $\log N$ against $\log I$ for various areas of sky, where N is the number of radio sources per unit solid angle of intensity greater than I. A typical $\log N/\log I$ plot, whose general shape holds good for seven areas of sky investigated, is shown in Fig. 3. The straight broken line corresponds to a slope of $-1{\cdot}5$, which is the calculated value for sources of uniform spatial density. The experimental curve becomes steeper for low intensities until a flattening due to instrumental limitations sets in. This seems to imply that the spatial density of radio stars increases with increasing distance from the solar system—a conclusion that has a most important bearing on the present rival cosmological theories. In the first of these, the continuous creation theory, the spatial density of nebulae is constant, but in the second, the evolutionary theory, it decreases at any point with time. On the second theory we should expect to find the density



1 *An artist's impression of the completed steerable telescope at Jodrell Bank*

The steel towers supporting the bowl are 170 ft high and are carried on bogies running on railway track. The foundations of reinforced concrete are up to 90 ft deep. The total weight of the steel superstructure is about 2 000 tons.
The drawing is reproduced by courtesy of Husband and Co., Sheffield.



2 *Calculated power gain and beam width of the telescope*

The power gain is shown relative to an isotropic radiator; the assumed efficiency is 60%.

increasing with the distance from us, since we view the state of celestial objects at the time that their light started travelling towards the earth—a time that may be as much as 2000 million years ago from objects near the limits of the observable universe. This expected variation is borne out by the type of plot shown in Fig. 3, and it seems that the present results of radio astronomy favour the evolutionary cosmological theory. But the data are at present too uncertain to produce an agreed solution to this fundamental and most important problem. Obtaining new data, as precisely as possible, about the spatial distribution of extragalactic sources will form an important part of the work with the new telescope.

In 1945 Van de Hulst predicted that the rare emission of photons from hydrogen atoms at a frequency of 1420 Mc/s, through a change in the orientation of the electron spin, should be detectable from the hydrogen filling interstellar space. This theory was verified in 1951, and thus began a new chapter in radio astronomy—the investigation of the 21 cm radiation from galactic hydrogen. Several observatories have built radio telescopes specially for this work, which has led, through study of galactic clouds of hydrogen, to remarkable information about the spiral structure of the Galaxy.

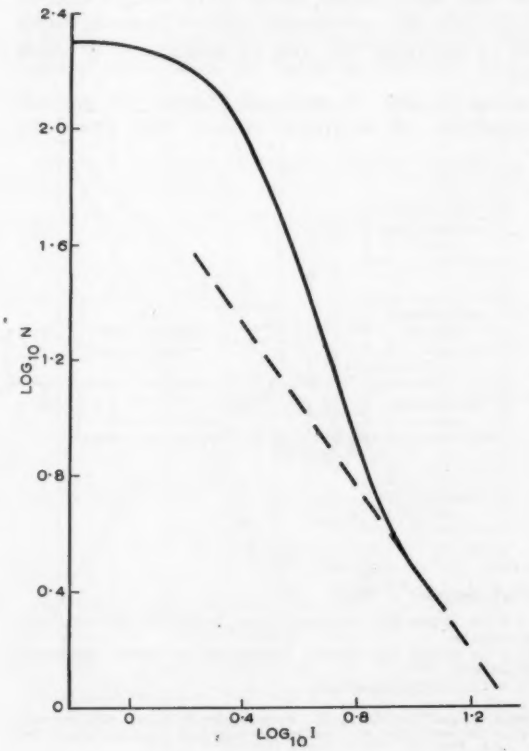
It is hoped that in good weather conditions the new Jodrell Bank telescope will be able to operate on 21 cm, and it is intended to develop an absorption method (already in use with smaller telescopes) for measurement of the distances of galactic radio sources, and to develop 'red-shift' measurements for extragalactic sources. The absorption method depends on the measurement of the absorption by neutral hydrogen of radiation of one frequency in a continuous-spectrum emission, and knowledge of the spatial distribution of the galactic hydrogen. It is not applicable to extragalactic sources, whose distances are, as already indicated, of great importance for the cosmological problem. In the normal telescopic measurements of distance of extragalactic nebulae, the red shift of known spectral lines is determined, and the distance obtained from Hubble's relation between distance and velocity of recession. An analogous radio method will be used, and the high gain and discrimination of the new Jodrell Bank telescope will be invaluable for this work. A major difficulty will be the large shift of line frequency; e.g. the shift of the 21 cm line in the Cygnus source is 80 Mc/s, since its speed of recession is 16800 km/s.

Another use for the new telescope will be as a combined radio transmitter and receiver to obtain radar echoes from celestial objects. This work will apply to the moon, sun, Venus and other bodies in the solar system. When a radio wave traverses the ionosphere, its plane of polarization is rotated, and this causes long-period fading of echoes from the moon, echoes which were first obtained in Hungary in 1946. The amount of rotation of the plane of polarization depends on the total electron density of the ionosphere, which can thus be determined by moon-echo experiments. Besides extending the work on the moon, an attempt will be made at Jodrell Bank to obtain radar echoes from Venus, a feat not yet achieved by any radio telescope. An overall power sensitivity of about a million times greater than that needed for moon echoes must be available. Moreover the complete return journey for the radio signal will take about 4 min. The difficulties are therefore formidable.

The telescope may also be used for investigating the recently discovered radio emissions from Jupiter and Venus. The origin and spectrum of these emissions are not known, but those from Jupiter have been studied on frequencies around 25 Mc/s. Opportunities for investigating the Jovian atmosphere and possible ionosphere by observation of these radio emissions are considerable, and work is now proceeding elsewhere.

In conclusion, it is hoped that the solar system studies carried out on the new telescope will make a significant contribution to the work of the International Geophysical Year, which begins in July 1957.

3 *The number of radio sources per unit solid angle of intensity greater than I plotted logarithmically against I for a typical area of sky*



SHORT REVIEWS OF PAPERS

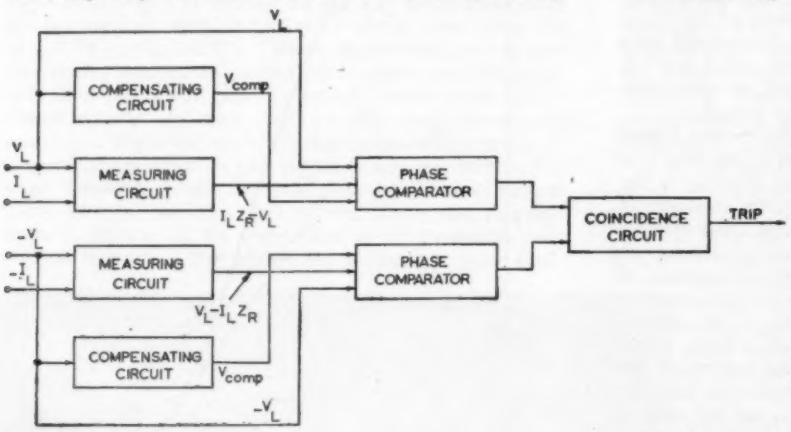
Transistor Distance Relays

A short review of a Supply Section paper (No. 2177) entitled 'A Dual-Comparator Mho-Type Distance Relay utilizing Transistors', by C. Adamson, M.Sc.(Eng.), Associate Member, and L. M. Wedepohl, B.Sc.(Eng.), Graduate. The paper was published individually in September 1956, and it was republished in October 1956 in Part A of the Proceedings.

IN AN EARLIER PAPER* THE POSSIBILITIES OF PRODUCING distance relays based on the properties of junction transistors were investigated. It was shown that relays based on a direct phase comparison of voltage at the relay terminals and fault current were practicable; difficulties arose, however, due to the presence of offset d.c. components in the fault current and voltage. Tests on early relays exposed severe transient-overreach factors and means had to be devised to overcome this particular difficulty.

There are three possible ways of eliminating transient overreach: (i) by using average values of voltage and current over one complete cycle, (ii) by using a filter to eliminate any d.c. component before applying input signals to the relay, and (iii) by duplication of input circuits.

Methods (i) and (ii) were not adopted, on grounds of complexity of electronic circuits and time-delay respectively. The present relay is based on method (iii) and is free from transient inaccuracies.



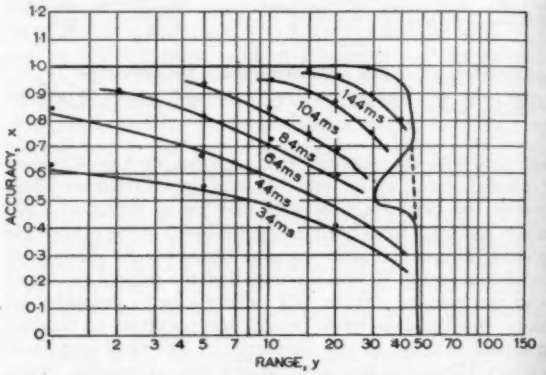
1 *Block diagram of relay*

V_L is the system fault voltage referred to the voltage-transformer secondaries.
I_L is the system fault current referred to the current-transformer secondaries.
Z_R is the transfer impedance.

* ADAMSON, C., and WEDEPOHL, L. M.: 'Power System Protection, with particular reference to the Application of Junction Transistors to Distance Relays', *Proceedings I.E.E.*, Paper No. 2085 S, August 1956 (103 A, p. 379).

Fig. 1 shows the block diagram of the relay, which is arranged to have a mho characteristic. The input circuits are duplicated, the signals being applied in anti-phase in the two circuits.

Fig. 2 shows a dynamic timing chart for the relay, with a 100% d.c. transient in the fault current. The ordinate in this chart represents the distance to the fault per unit of the nominal relay setting, and is known as the accuracy x; the abscissa is the range y, which is the system source impedance expressed again per unit of the nominal relay setting. The parameters of the chart are fixed times of operation. It may be seen from this chart that there is no transient overreach. There is, however, a time-delay for marginal faults which does not occur for zero transient. It is shown that the transient time-delay is a function of the point of switching, range and position of fault; further research work has indicated that this time-delay can be eliminated.

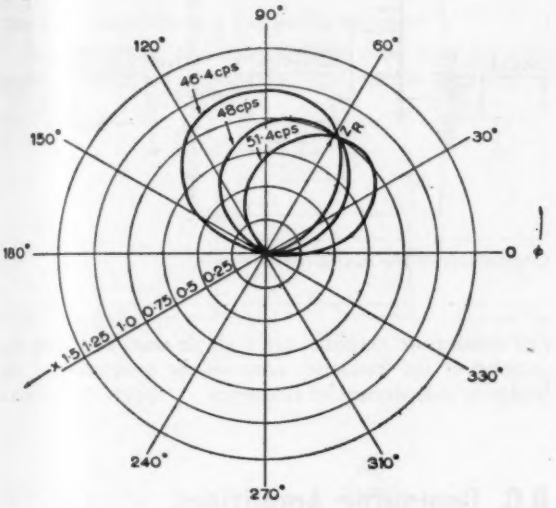


2 *Accuracy/range chart for relay with memory*
Operating times for a 100% d.c. transient are shown.

An important refinement of this relay is a reduction in input sensitivity consequent on the use of a delay circuit to compensate for the finite operating potential. The effect is to maintain the accuracy of the relay over a range of approximately 50; this may be seen from the accuracy/range chart (Fig. 2).

A number of tests were conducted with a tuned circuit

to sustain the polarizing voltage in the event of a fault near the relay terminals. These tests, involving memory action, have indicated that this type of relay is probably suitable for all faults up to the relay terminals. This is possible because of the short time-constant of the tuned circuit. Dynamic polar curves of the relay with memory, for different values of supply frequency, are shown in Fig. 3.



3 *Dynamic polar curves for relay with memory*

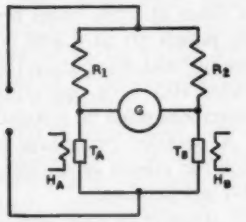
This relay shows a marked improvement over earlier transistor relay prototypes, particularly with regard to accuracy and the absence of transient overreach. Confidence in transistors and the dual-comparator circuit configuration is well established. Present work is concerned with the design of a complete transistor distance relay terminal.

621.318.57 : 621.314.7

A.C. Measurement by Thermistor

A short review of a Measurement and Control Section paper (No. 1989) entitled 'The Indirectly Heated Thermistor as a Precise A.C.-D.C. Transfer Device', by F. C. Widdis, B.Sc.(Eng.), Associate Member. The paper was published individually in February, 1956, and it is republished this month in Part B of the Proceedings.

THE PRECISE MEASUREMENT OF AN ALTERNATING CURRENT is readily effected with a thermal device in which the heating effect of the alternating current is compared with that due to an accurately known direct current. The indirectly heated thermistor, comprising a bead of thermally sensitive resistance material surrounded by a heater, can be used for this purpose, with the advantage of a high sensitivity in the measurement. It is essential to use a balanced bridge arrangement such as in Fig. 1 in order to minimize the effects of ambient temperature changes. T_A and T_B are two indirectly heated thermistors. The resistor R_2 is made variable in order to perform the initial balance of the bridge. A 9-volt battery is used for



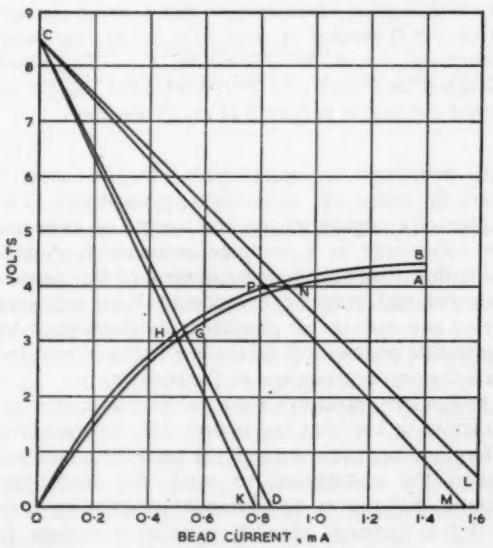
1 *Bridge arrangement of two indirectly heated thermistors*

H_A, H_B = Heaters.
T_A, T_B = Thermistor beads.

the supply, and the detector is a portable reflecting galvanometer.

The device may be used for standardizing purposes in a.c. potentiometry, and then a known direct current is passed through the heaters in series and the bridge balanced by adjustment of R_2. One heater is switched to the a.c. circuit and the alternating current adjusted until the bridge is again balanced, the direct current being maintained at its correct value in the other heater. The magnitude of the alternating current is then accurately known.

The effects of ambient temperature changes are negligible if the operating temperatures of the beads are the same. This condition can largely be met by shunting one heater so that the ratio of heater power to dissipation constant is the same in both. The constructional differences in bead resistance result in slightly different bead currents when the bridge is balanced, and cause



2 *Bridge operating conditions for 10 mW initial heater dissipation and a bridge supply of 8·5 volts*

The line CGD corresponds to a value of 10 000 ohms for R_1 and line CNL to 5 000 ohms. Air temperature, 16·6° C.

additional small differences in bead temperature. Typical operating conditions for the bridge, with a value of 10000 ohms for R_1, are shown in Fig. 2, the operating points for the thermistors being at H and G respectively. The horizontal difference HG is a measure of difference in bead dissipation and therefore in bead temperature. The line CNL corresponds to a value of 5000 ohms for R_1, and at balance the operating points are at P and N. PN is a measure of the difference in bead dissipation for this condition, and is about twice HG. The operating bridge voltage and the series resistances must be selected to keep this difference small. A detailed procedure is given which, if followed, reduces the effects of ambient temperature changes to negligible proportions.

Errors also appear in thermal transfer devices due to Peltier and Thomson effects in the d.c. tests. The reversal differences encountered were extremely small, and it is considered that these effects were negligible. Errors due to various non-linear effects arising during the a.c. tests also occur. Expressions developed for these non-linear errors show that they are insignificant for operating frequencies above 0·2 c/s. The upper frequency limit is determined by the electrical constants of the heater and this is estimated to be of the order of 1·5 Mc/s for a 0·1% error.

The overall transfer error is estimated to be within ±2·5 parts in 10^4 between 0·5 c/s and 0·5 Mc/s.

621.317.7.082.64 : 621.316.89

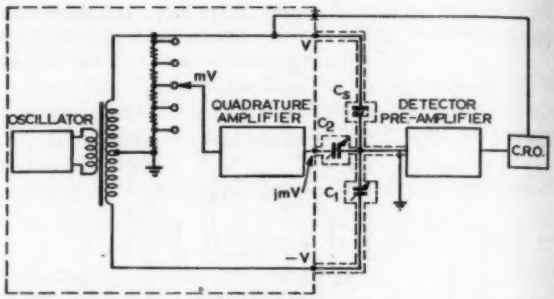
Permittivity Bridge

A short review of a Measurement and Control Section paper (No. 1963) entitled 'A Bridge for the Measurement of Permittivity', by A. M. Thompson, B.Sc. The paper was published individually in December 1955 and it is republished this month in Part B of the Proceedings.

THE A.C. PROPERTIES OF DIELECTRICS ARE MOST SIMPLY expressed in terms of a complex permittivity. The admittance of a capacitor with the sample as dielectric may be considered as a complex capacitance. A null method is described for the measurement of this capacitance, the real and imaginary components being indicated directly on two variable air capacitors. Multiplication by an appropriate geometrical factor is all that is required to obtain the two components of the permittivity.

The bridge uses transformer ratio arms whose effective impedance is so low that the sample may be measured as a 3-terminal capacitor without the need for a separate balance of the admittances to earth. To enable the conductance balance to be obtained an amplifier controlled by a feedback network supplies a voltage in quadrature with that of the transformer. The arrangement of the bridge is shown in the diagram. With the nominal voltage distribution shown, $C_s = C_1 - jmC_2$, where m is the attenuator multiplying factor. The effect of imperfect voltage ratios is examined together with the limitations of the transformer ratio arms and quadrature amplifier.

The bridge operates at ten fixed frequencies from 30 to 10^6 rad/sec. The oscillator, transformer ratio arms and quadrature amplifier are a single unit, and with the ganging of the frequency controls the operation of the bridge is independent of frequency. 621.317.733 : 622.335.3



Components of the measuring system

D.C. Computer Amplifiers

A short review of a Graduate and Student Section paper entitled 'A Review of Recent Work and Development in D.C. Computer Amplifiers', by J. A. Bottomley, M.Sc.Tech., Graduate. The paper was awarded a Students' Premium by the Council.

AMPLIFIERS FOR ANALOGUE COMPUTING, PERFORMING such mathematical operations as addition, integration and differentiation, must generally cover a range of frequency from zero (i.e. direct current) upwards. The term 'd.c. amplifier' here implies the use of a device amplifying both direct and alternating current components, which has, in general directly coupled stages.

Direct current amplifiers introduce zero-drift problems because any small changes of valve electrode potentials are transmitted through the conductive interstage coupling networks. These small voltages are subsequently amplified, and produce an out-of-balance or error voltage at the output. Any constant error voltage is reduced to zero by a zero-setting voltage control. This zero-setting voltage is obtained by variation of the grid/cathode potential on one of the early stages. If the error voltage is variable with time, it is known as drift, and special designs of input stage are used to effect its reduction.

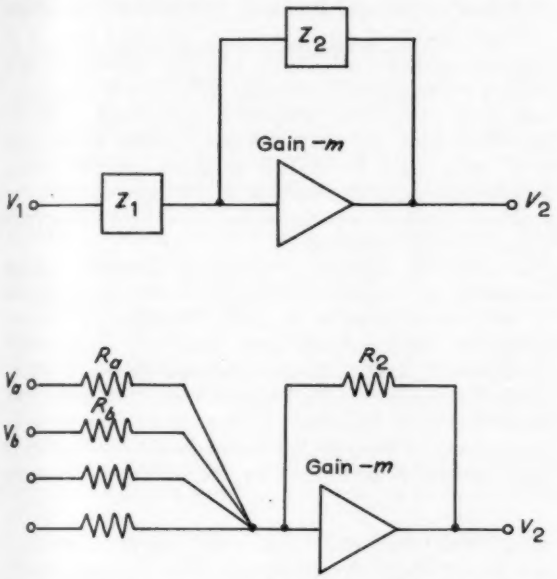
Conductive coupling involves the connection of a high-potential point and a low-potential point with respect to earth (anode and grid respectively) when stages are connected in cascade. There are a number of

methods of achieving this, but the method of resistive coupling and the use of one or more negative h.t. supplies is now the most popular.

D.C. amplifiers for analogue computation are usually high-gain devices, and are often used with appreciable negative feedback. Here, an additional problem is stability against oscillation at high frequencies.

The D.C. Amplifier as a Computing Element

The connection of a d.c. amplifier when used for analogue computation is shown in Fig. 1(*a*). The gain (V_2/V_1)



1 *Connection of a d.c. amplifier used for analogue computation*
(*a*) Basic circuit. (*b*) Summing amplifier.

can be shown to be $-Z_2/Z_1\{1/[1 + 1/m(Z_2/Z_1 + 1)]\}$, which, if $m \to \infty$, becomes nearly $-Z_2/Z_1$, where Z_1 and Z_2 are the input and feedback impedances respectively.

With suitable combinations of Z_2 and Z_1, the amplifier can be made to perform several mathematical operations. The simplest of these are multiplication by a constant, integration and differentiation, which occur when Z_2/Z_1 is equal to R_2/R_1, $1/pCR$ and pCR respectively. It should be noted that in all cases there is a sign reversal between input and output voltages.

If Z_1 and Z_2 are resistances, and Z_1 is replaced by a number of parallel resistances R_a, R_b, . . . , and if voltages V_a, V_b, . . . are applied to R_a, R_b, . . . respectively, then the output V_2 is given by

$$V_2 = -R_2(V_a/R_a + V_b/R_b + \ldots)$$

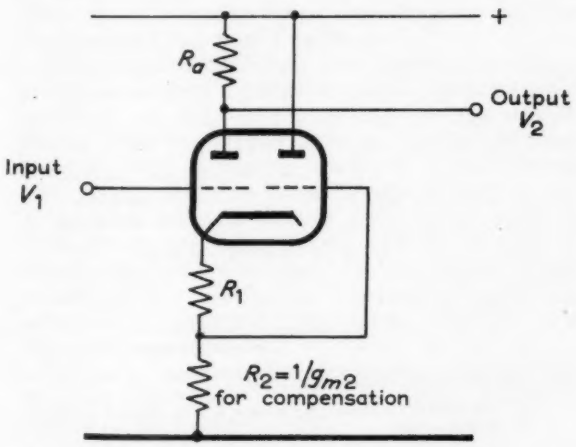
The output is thus the sum of the input voltages, and the arrangement, shown in Fig. 1(*b*), is called a summing amplifier.

Errors and Error Reduction in D.C. Amplifiers

In an ideal d.c. amplifier, there is zero output (a.c. or d.c.) for zero input. In practice, unwanted signals occurring in the amplifier produce an error voltage and drift at the output.

Drift arises from many sources, the most important being the variation of heater and h.t. supplies, component and valve instability and noise, and variation of the contact potential difference between grid and cathode of the first valve.

To minimize drift, well-stabilized h.t. supplies are used. High-stability resistors and resilient mounting of valves—particularly the first—are desirable. To minimize heater drift, special circuits such as those of Miller* and Artzt† are often used. The basic Miller heater-drift-compensation circuit is shown in Fig. 2.



2 *Heater-drift-compensation circuit*
g_{m2} is the mutual conductance of the second half of the double triode.

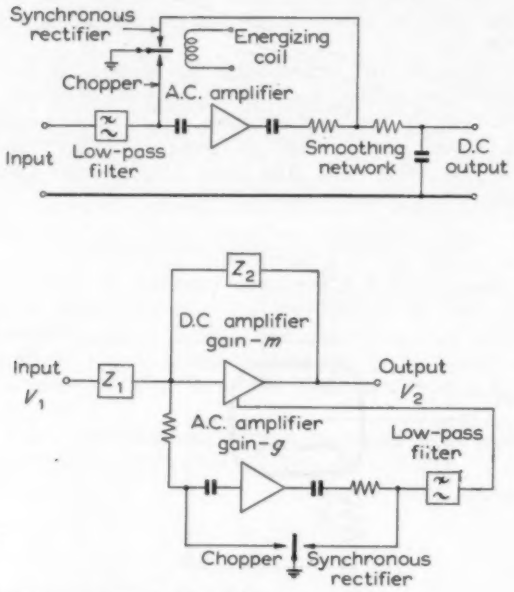
Errors arising from grid current in the first valve may be appreciable if a high value of input resistor is used, but such errors can be virtually eliminated by the use of electrometer-type valves.

Drift can be reduced considerably by the use of auxiliary and more complicated circuits. Two such methods are outlined below.

(*a*) *Conversion to alternating current.* This is used only when the signals to be amplified are direct current or very-low-frequency alternating current. The input signal is interrupted by a 'chopper' relay converting it to alternating current, amplified by a driftless a.c. amplifier and then synchronously rectified and smoothed. The system, which is shown in Fig. 3, operates satisfactorily up to signal frequencies of about one-tenth of the chopper frequency, the frequency limitation being that of the chopper relay.

* Miller, S. E.: 'Sensitive D.C. Amplifier with A.C. Operation', *Electronics*, November 1941, **14**, p. 27.
† Artzt, M.: 'Survey of D.C. Amplifiers', *Electronics*, August 1945, **18**, p. 112.

(*b*) *Chopper and associated a.c. amplifier.* This is a hybrid system which incorporates an a.c. and a d.c. amplifier.* A block diagram is shown in Fig. 4. The current at the summing point is converted to alternating current by the chopper relay, amplified in the driftless a.c. amplifier, synchronously rectified, smoothed to remove components of chopper frequency, and reapplied



3 *Circuit for the reduction of drift*

(*a*) Conversion to alternating current and subsequent smoothing. (*b*) Hybrid system.

to the d.c. amplifier at some point at which a zero-setting voltage can normally be applied.

If the d.c. amplifier has an error voltage d referred to the signal input grid, it can be shown that the output voltage is given by:

$$V_2 = [-V_1 k - d(k+1)/(1+g)]/[1+(k+1)/m(1+g)]$$

where $k = Z_2/Z_1$, m is the open-loop gain of the amplifier and g is the gain of the chopper loop. It should be noted that the error voltage d can comprise both a steady direct-current offset and drift. In an uncorrected amplifier ($g = 0$) the output error term is $d(1 + k)$. This error term is reduced by a factor $(1 + g)$ on introduction of the chopper system.

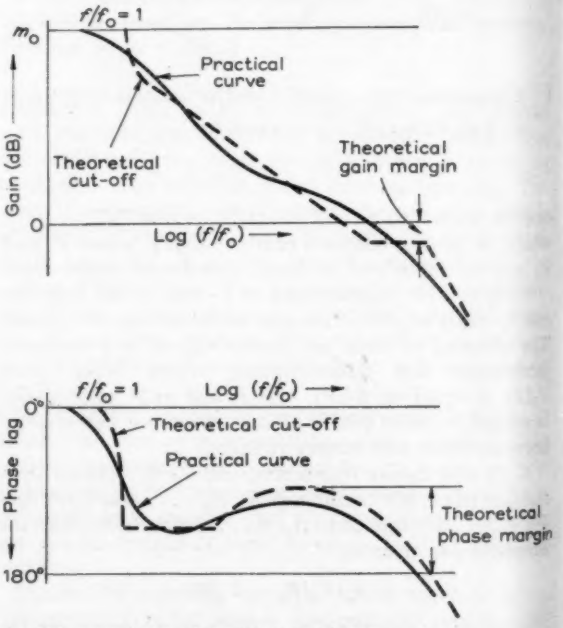
The effective gain of the d.c. amplifier is increased by the factor $(1 + g)$, but this is maintained only up to very low frequencies since g falls rapidly with frequency. The high-frequency gain of the system is that of the amplifier itself. Because the bandwidth of the a.c. channel is very small, only direct-current and very-low-frequency error signals are reduced. Drift is normally of a very-low-frequency nature, and so the drift component of the output error is also reduced by the factor $(1 + g)$. The constant component of the total error d is first reduced to zero by a normal zero-setting control.

The grid-current error, which is unaffected by the introduction of the chopper system, can be eliminated by the use of electrometer-type valves, and the drift of the d.c. amplifier can be reduced to a negligible value by making the gain of the a.c. amplifier sufficiently large. The limiting value of output drift is governed primarily by the stability of the chopper relay.

Additional Errors and Problems of Computer Amplifiers

It has already been shown that the ideal gain of a computer amplifier is $-Z_2/Z_1$, and that this occurs only when m is infinite. The finite-gain error, to a first approximation, is $(k + 1)/m$, where $k = Z_2/Z_1$ and m is the open-loop gain. To keep this error as low as possible m is made large (80–100 dB at direct current). Since considerable negative feedback is normally applied, the problem of stability against oscillation at high frequencies is one of prime importance.

In order to stabilize a computer amplifier against oscillation, an accurate knowledge of stray capacitances in valve and circuit is desirable. Stabilization can be effected by the simulation of an ideal theoretical cut-off characteristic, chosen to give adequate gain and phase-stability margins. The final cut-off asymptote, and hence the initial cut-off frequency, are dependent upon the stray capacitances of the amplifier. Simulation of the theoretical characteristic is performed by the insertion of known



4 *Characteristics of computer amplifiers*

(*a*) Gain/frequency characteristic. (*b*) Phase/frequency characteristic.

* Goldberg, E. A.: 'Stabilization of Wide-Band Direct-Current Amplifiers for Zero and Gain', *R.C.A. Review*, 1950, 11, p. 296.

phase lags and leads (stabilizing networks) in the amplifier. A simple form of stabilizing network is a series CR combination. Typical gain and phase cut-off characteristics, plotted against the logarithm of frequency, are shown in Fig. 4.

Because of the high open-loop gain (and hence drift) of a computing amplifier, direct plotting of the open-loop characteristic is not practicable, but since relationships exist between open- and closed-loop gain and phase shift, the important portion of the open-loop characteristic can, under certain conditions, be found from the knowledge of a closed-loop characteristic, the plotting of which is relatively easy.

Typical Performance of a Computer Amplifier

A typical amplifier with an open-loop gain of about 70000, has an open-loop band-width ($f = m_0/\sqrt{2}$) of between 100 and 200 c/s, and, with unit gain, a closed-loop bandwidth ($f = G_0/\sqrt{2}$) of about 20000 c/s (m_0 and G_0 are the open- and closed-loop gains respectively at direct current).

With a Miller heater-drift-compensation input stage and stabilized h.v. supplies, the drift, referred to the amplifier input, is less than 5 mV/h. The same order of drift is encountered in an amplifier using balanced stages, but in the drift-corrected amplifier shown in Fig. 3(*b*) the drift over a period of several hundred hours is of the order of only $\pm 100\,\mu$V referred to the input. In this last instance, the output drift as an integrator ($CR = 0{\cdot}025$ sec) is less than 50 mV/min.

In a well-constructed amplifier, ripple and noise voltages rarely exceed 10 mV (d.a.p.) referred to the amplifier input.

Since computer amplifiers often have to work into low-impedance loads (sine/cosine potentiometers), cathode-follower output stages are normally used. An output-voltage swing of ± 50 volts when driving a sine/cosine potentiometer (5 500 ohms) is desirable.

621.375.2 : 621.374.32 : 681.142

Servo Mechanisms

A short review of a Graduate and Student Section paper with the above title by J. Jardine, B.Sc.(Eng.), Graduate. The paper was awarded a Students' Premium by the Council.

IN THE APPLICATION OF SERVO MECHANISMS A GIVEN system must respond satisfactorily to the type of input it receives; thus it is necessary to predetermine the performance at the design stage. Such basic characteristics as speed of response, initial overshoot, degree of damping and steady-state-following errors are often considered sufficient to describe the performance of the system in a particular application. These characteristics are determined from the transient behaviour of the system in which the shape of the curves is the important factor. The system could also be examined on a steady-state basis but the usefulness of such a response is limited in comparison with the transient response.

Unfortunately, in design work, the analysis of a system on a transient basis presents analytical difficulties owing to the complexity of the operational equations associated with the system. Thus the advantage of simplicity in measuring the transient response is offset by this analytical complexity in design. On the other hand, with frequency response, the practical measurements are more difficult. Mathematical steady-state analysis presents no great problem since the total response of a system can easily be obtained from a knowledge of the frequency response of its individual components. It would then seem desirable to be able to design servo mechanisms on the basis of frequency response, knowing that the transient behaviour would be satisfactory. For this to be possible it is necessary to know the relationship between the transient response and frequency response of the system.

Such a relationship between the important parameters of the closed-loop transient response and some parameters of the open-loop frequency response may be derived. This relationship is in the form of empirical formulae (with no relating theory) by means of which much of the complexity in servo design is removed. The investigation takes the form of a theoretical approach, whereby data concerning the responses of two types of servo mechanism are obtained, and, by a suitable choice of parameters of their frequency responses, simple linear relationships concerning rise time, overshoot, and relaxation time are derived.

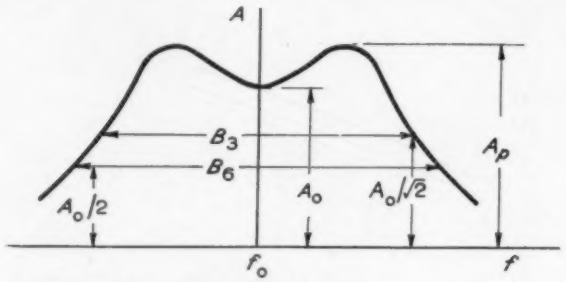
An exact mathematical relationship between the frequency and indicial responses of a servo mechanism is given by the Fourier integral

$$F(t) = \frac{1}{2\pi}\int_{-\infty}^{+\infty} \frac{G(j\omega)}{1 + G(j\omega)}\, \varepsilon^{j\omega t} d\omega$$

where $F(t)$ is the response to a unit impulse input, $G(j\omega)$ is the general steady-state frequency response of the open loop, and t is the time. It is obvious that the solution of this integral could be very involved except in the simplest examples. Various methods, both graphical and mathematical, have been suggested to simplify the frequency/time transformations, but most of them suffer from limitations in the range of frequency of interest to designers of servo mechanisms. Z. Jelonek and Z. E. Jaworski* found an empirical relationship between some parameters of the amplitude/frequency response and other parameters of the indicial response. From data concerning the response of several dozen typical multi-stage networks used in radio receivers, and by a judicious choice of parameters of their frequency response, Jaworski derived linear relationships. These are simple to apply (having only four easily measured parameters) and show a fair degree of accuracy when applied to a type-1 servo mechanism.

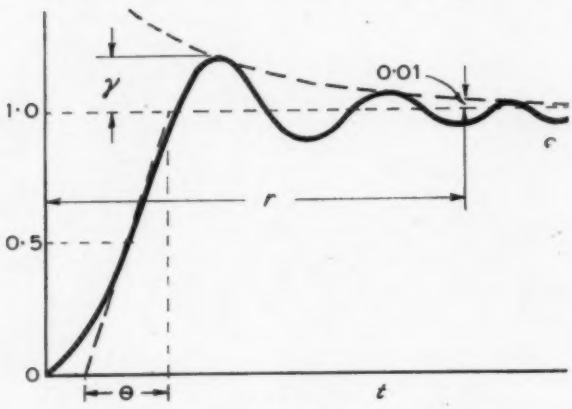
* JAWORSKI, Z. E.: Correlation between the Indicial Response and Frequency Response of Electrical Networks'. Unpublished.

In order to derive such empirical relationships the author carried out mathematical analyses of type-1 and type-2 servo mechanisms. Families of curves, representing the open- and closed-loop frequencies and transient



1 *Closed-loop frequency response*

responses, were predicted for various values of the system constants. By suitably combining the frequency parameters, simple relationships were found between these combinations and the transient parameters. The



2 *Closed-loop transient response*

following empirical formulae were then derived by the method of least squares:

$$\theta = 0{\cdot}675/B_3$$
$$\gamma = 41{\cdot}5 \log_n (A_p.B_3/B_6) + 16{\cdot}75$$
$$r = (6{\cdot}12A_p.B_3/B_6 - 1{\cdot}51)/B_6$$

where the parameters, illustrated in Figs. 1 and 2, are defined as follows:

B_3 is the bandwidth at the 3 dB level below the zero-frequency value.

B_6 is the bandwidth at the 6 dB level below the zero-frequency value.

A_p is the peak amplitude of the frequency-response curve.

θ is the rise time, i.e. the time interval marked off by the tangent to the response curve at half the steady-state amplitude, between zero amplitude and the steady-state value.

γ is the overshoot, i.e. the difference between the first maximum of the response curve and the steady-state value, expressed as a percentage of the steady-state value.

r is the relaxation time, i.e. the time taken from zero amplitude of the transient response to the moment when the envelope of the response deviates from the steady-state value by 1% of that value.

The above parameters refer to the closed-loop conditions. Since it is desirable to have a direct indication of transient parameters from the open-loop response, some method is needed of deriving the closed-loop frequency parameters from the open-loop frequency-response curve. This is done by using a graduated-grid arrangement of curves having constant A_p, constant B_3, and constant B_6, by means of which the desired frequency parameters are obtained from an accurate plot of the open-loop response curve.

In practice the rise time gave a maximum inaccuracy of 12·5%, while the r.m.s. value of all inaccuracies was 9·15%. A more complex relationship, $\theta = (a\gamma + b)/B_6$, where a and b are constants, gave a higher degree of accuracy, but for the sake of simplicity the first relationship was adopted. The overshoot gave a maximum inaccuracy of 10% and an r.m.s. value of 4·25%, while the figures for relaxation time were 13% and 6%.

In an attempt to verify the application of the empirical formulae a type-1 servo system was designed and experimental data were obtained from it. On applying the formulae to the system it was found that apart from overshoot large inaccuracies were apparent. These were due to non-linearities in the loop rather than to inaccuracies in the empirical relationships, since the latter were derived from a consideration of linear conditions.

621–526

Spark Generated Microwaves

A synopsis of a Radio and Telecommunication Section paper (No. 2185) entitled 'Researches into Spark Generation of Microwaves', by M. H. N. Potok, B.Sc., Ph.D., Associate Member. The paper is published this month in Part B of the Proceedings.*

A STUDY OF MICROWAVE SPARK GENERATORS SHOWS THAT they have certain useful characteristics. In particular, the wide band of frequencies generated permits the use of filters to select a desired band of any width. Both post and iris types of filter were used. The measurements of wavelength and bandwidth were carried out with the help of a Boltzmann interferogram using a cathode-ray oscilloscope and a camera for recording purposes. Very satisfactory results were obtained in the 2–4 cm region, and less satisfactory results down to 8 mm. 621.373.2.029.6

* See p. 684.

Papers read at the Convention on Digital-Computer Techniques, April 1956

The remainder of the short reviews published this month is a final selection of reviews of papers read at the Convention on Digital-Computer Techniques, which was held by The Institution from the 9th to 14th April 1956. Previous selections were included in the August, September and October *Journals*. Papers Nos. 2144 and 2156 were read at General Sessions of the Convention and the remainder of those appearing below at Specialist Sessions. The complete papers are being published in special supplements to the *Proceedings*, as announced in the July *Journal*, p. 446. Supplements Nos. 1 and 2 are now available, and the third supplement will appear later this month.

Machine Translation

Paper No. 2144 entitled 'An Experiment on the Machine Translation of Languages carried out on the BESM', by I. S. Mukhin.

WORK ON MACHINE TRANSLATION FROM ENGLISH INTO Russian was started in January 1955, as a joint work of two Institutes of the Academy of Sciences of the U.S.S.R. The experiments were carried out on the BESM high-speed electronic computer, designed and constructed by Professor S. A. Lebedev. By the end of the year the first results had been achieved.

The texts selected for translation were a number of excerpts from W. E. Milne's 'Numerical Solution of Differential Equations' together with some other texts of different specification (e.g. an article from *The Times*, shown with its Russian translation in Fig. 1).

The dictionary compiled for the purpose differs from the usual type in that it not only gives the so-called 'dictionary meanings' of the words, but reflects the life and language connections, which determine their possible applications.

The dictionary consists of an English section and a Russian one. There is a special section for words having multiple meanings. The words of the English text are found in the dictionary by the operation of comparison, performed by the computer, the grammatical affixes being previously discarded by the process shown diagrammatically in Fig. 2. The words found in the dictionary are replaced by their numerical equivalents. A word not found is printed in Latin script (see Fig. 1).

The two independent parts of the translation programme are the English analysis and the Russian synthesis, the latter being useful for translating from any language.

The results are automatically printed in Russian script on a paper tape.

NO WORK OF ART

Dr. Booth said that there was no machine in existence—at any rate on this side of the Iron Curtain—which had anything like the storage capacity which was needed for translating a book, or for that matter, even a general piece of scientific text. The speaker at Cheltenham evidently had a version of an experiment done in the United States two year ago, he said. " This was based on an expensive experiment done by myself and Dr. R. H. Richens, of Cambridge University, in which we worked out a method of translating small sections of selected text in foreign languages. We gave an account of this at a conference in Massachusetts in 1952, after which the International Business Machines Company, in conjunction with Georgetown University, applied our methods to give a popular demonstration which was limited to translating a few sentences from Russian into English. There is no possibility at present of translating a book as a work of art.

" The important factor is not the length of the text but the size of the dictionary which can be stored in the computing machine, and so far scientists have been limited to a vocabulary of about 1,000 words. With a text which is within this range, the machine can operate, but when it receives a word which is outside this range the machine detects that it cannot make sense of it and puts out the word in the foreign language.

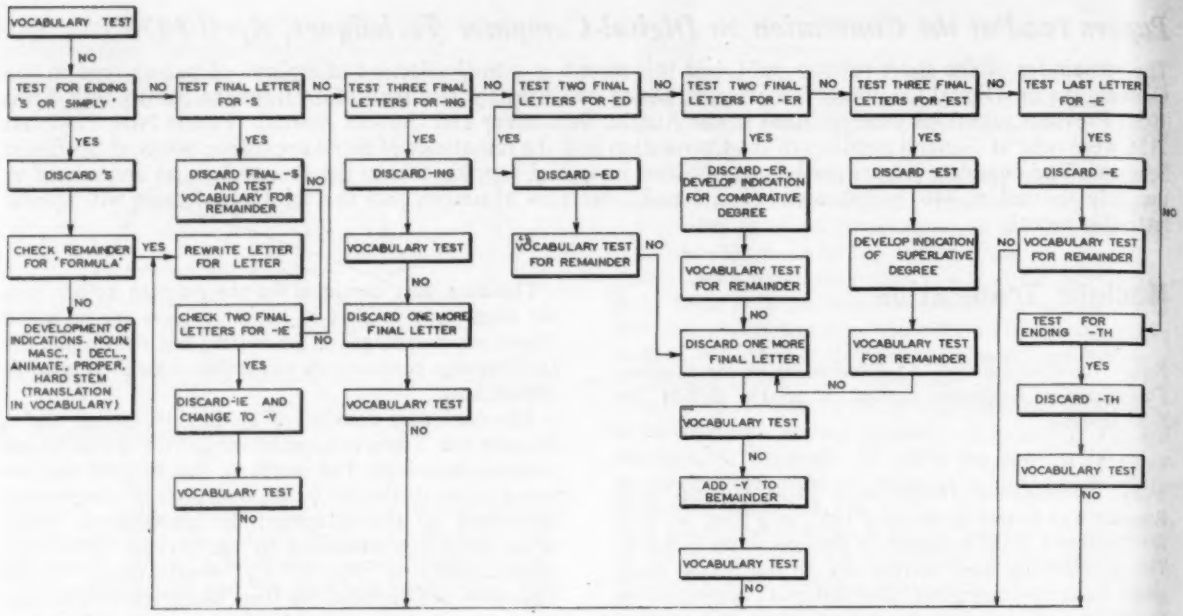
(THE TIMES FRIDAY OCTOBER 21 1955)

НЕ ПРОИЗВЕДЕНИЕ ИСКУССТВА

Доктор Booth говорил что не имеется машины в мире - во всяком случае на этой стороне - Iron Curtain -, которая имеет нечто вроде памяти объема, который требуется для перевода книги или содержания общего отрывка специального текста. Оратор в Cheltenham очевидно имел в виду эксперимент проведенный в Соединенных Штатах два года тому назад, он говорил. Это было основано на дорогом экспериментe произведенном мной и доктором R.H.Richens, от Кембриджского Университета, в котором мы разработали метод перевода малых отрывков выбранного текста на иностранные языки. Мы дали отчет о этом на конференции в Massachusetts в 1952, после которого I.B.M.компании в сотрудничестве с Джорджтаунским Университетом применили наши методы чтобы дать наглядную демонстрацию, которая была ограничена переводом нескольких предложений с русского на английский.Не имеется возможности в настоящее время перевода книги как произведения искусства.

Важный показатель есть не длина текста но размер словаря, который может храниться в вычислительной машине и поэтому ученые были ограничены словарем приблизительно 1000 слов. С текстом, который внутри этого объема, машина может оперировать, а если она встречает слово, которое вне этого объема машина обнаруживает что она не может сделать заключение о этом и выводит слово на иностранном языке.

1 *An example of machine translation*



2 *Block schematic of translation process*

Recently the principles worked out for the English-Russian translation were applied to the machine translation of some other languages. 681.142:8.03

Electromagnetic Delay Lines

Paper No. 1990 entitled 'The Use of Electromagnetic Delay Lines in the Manchester University Mark II Digital Computing Machine', by G. E. Thomas, M.Sc., Ph.D.

IN THE BASIC DESIGN OF A COMPUTER THE USE MADE OF time in controlling the sequence of operations has probably the most important single influence on the characteristics of the final machine. Thus, the distinction between the two main types of digital computer, the serial and parallel, is made on a time basis. If the serial mode of operation is adopted with its consequent economy of equipment, it is necessary to use time to define and control the operations on each digit of the numbers used in computation. This exacting use of time in a high-speed computer is facilitated by the provision of a high-frequency oscillator which becomes the clock or time standard.

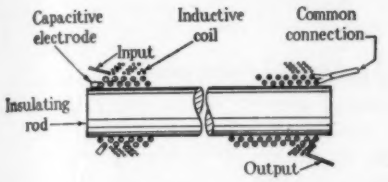
In addition to these time-defining waveforms, there exist circuit elements possessing an electrical characteristic which is time dependent and which is a function of their circuit constants only. These elements can, therefore, introduce a time control independent of the rest of the machine. Simple *RC* networks belong to this class and can be used to perform the functions of phase shifting, differentiation and integration. In a digital machine the *RC* network is found to be unsuitable for number handling and its application is restricted to the generation of timing waveforms, which in turn control number manipulation. The *LC* networks, either of the continuous or lumped variety which possess an electrical time-delay characteristic, are more suitable for number handling and have already found widespread application for the storage of numbers in regenerative registers.

In the Manchester University Mark II computer it has been found possible to exploit the continuously wound type of electromagnetic delay line to the best possible advantage. The fundamental frequency of this machine is 1 Mc/s, which permits an economic design of delay-line unit in the first instance, and which also determines the use of some form of delay-line store in the subsidiary registers. The floating-point accumulator, which forms such an important part of the new design, also requires a mechanism for the shifting of two numbers relative to one another; in a serial machine this implies the delay of one serial pulse train relative to another, again most conveniently performed with delay lines. While the two functions of number storage and number transfer form the major applications in the Mark II machine, several other interesting uses have been made of these relatively unconventional circuit elements.

The line giving a total delay of 443 microsec employed in the machine is considered to have contributed very significantly to the three improved features that the Mark II machine bears in relation to the Mark I version produced in 1951. These features are an increase in speed of computation, an improvement in mathematical facility

by the provision of the floating-point accumulator, and a reduction in size.

The design of cheap and reliable delay-line units for the Mark II machine was essential, so that their application would be unhampered by economic considerations. The way in which this was accomplished is illustrated in the diagram. The mechanical support for the delay line



Delay-line construction

is furnished by a 7-inch rod of any insulating material of circular cross-section and of $\frac{1}{8}$-inch diameter.

A first helix of insulated conducting wire is wound along the full length of the rod; this is then covered by a second helix of the same wire wound in the same rotary direction but in the reverse longitudinal direction. The double helix forms the common capacitance electrode of the delay line. The effective inductance of this winding is reduced to a negligible value by making electrical connection only to the reversal point of the double helix which is situated at one end of the line, the two free ends of the complete winding being left open-circuited.

The main inductive coil, which comprises about 4700 turns of 46 s.w.g. insulated copper wire, is wound on top of the capacitance winding in a controlled pattern. The first turn of the pattern is a plain circumferential one, without any longitudinal displacement relative to the rod. The second turn consists of an opened helix finishing at a point about $\frac{1}{8}$ inch displaced along the length of the rod. The third turn is another plain turn like the first. The fourth and final turn is a second opened helix like the second turn but displaced in the opposite direction along the rod so as to return just short of the first turn. The winding slowly progresses in this fashion along the 6 inches of rod giving a total winding of an average depth of four layers.

The materials in this simple structure are of negligible cost, and the production time is only half an hour with small workshop facilities. The bandwidth of a single 1 microsec section of the form described is 3 Mc/s and the characteristic impedance is 1·5 kilohm.

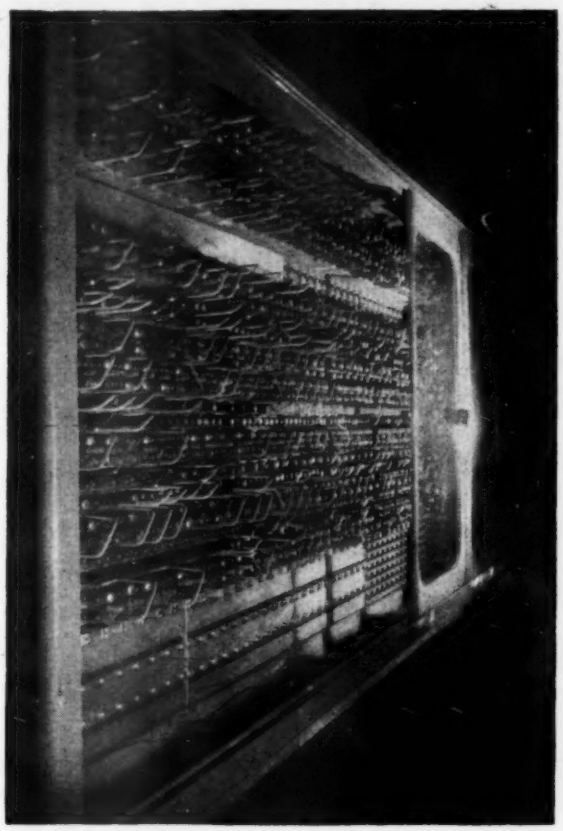
621.374.5 : 621.374.32

BESM Computer of the U.S.S.R.

Paper No. 2156 entitled 'The High-Speed Electronic Computer of the U.S.S.R. Academy of Sciences (BESM)', by V. A. Melnikov.

THE BESM IS A HIGH-SPEED DIGITAL ELECTRONIC COMPUTER for the solution of laborious problems in physics, mechanics, astronomy, engineering, etc. A general view of the computer is shown in Fig. 1. It can operate with numbers ranging from 2^{-31} to 2^{+31}.

In designing the BESM emphasis was laid on convenience in programming and simplicity in maintaining the machine.

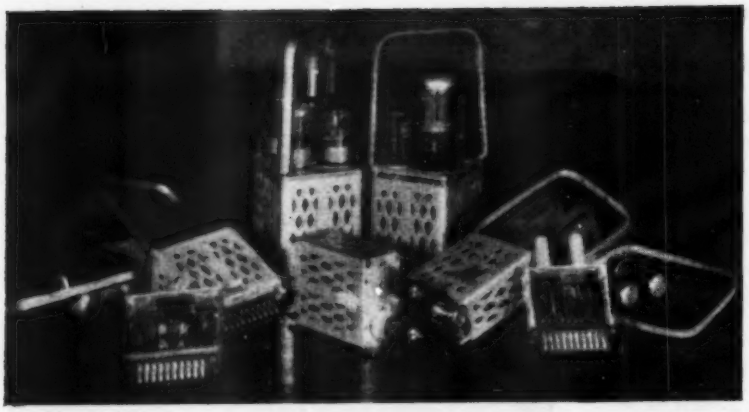


1 *General view of the BESM computer*

The computer is basically made up of separate standard plug-in units assembled on two-tube or four-tube chassis, as in Fig. 2. All the operations are carried out by a single universal parallel-action arithmetical unit. Special cathode-ray tubes are employed for the store, which has a capacity of 1023 numbers.

To extend the sphere of solvable problems and to include such as require large storage capacity, the computer is provided with magnetic-drum and magnetic-tape storage. The magnetic drum has a capacity of 5120 numbers. The capacity of the magnetic tape storage is 120000 numbers.

The input of numbers and instructions is mainly from punched tape. The results of the calculations are recorded on magnetic tape, and a photoprinter, an independent device, is utilized to print them afterwards on a film.



2 *Standard plug-in units*

Besides the photoprinter, there is an electromechanical printer, controlled directly by the computer.

The average operation speed in solving complex problems is from 7000 to 8000 three-address operations per second, reference to the magnetic-drum and magnetic-tape storage included.

The computer operates 24 hours per day, part of the time being spent on checking. The useful operating time of the computer is 72%, the time spent on checking is 20%, and error losses total 8%, including the time required to find the source of the trouble as well as the time needed for repeating the calculations. 681.142

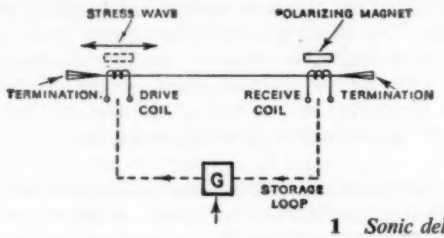
Sonic Delay-Line Store

Paper No. 2041 entitled 'A Sonic Delay-Line Storage Unit for a Digital Computer', by J. W. Fairclough, B.Sc.Tech., Student.

THE PAPER DESCRIBES AN INEXPENSIVE SERIAL STORAGE unit with a capacity of 42 digits at 3 microsec spacing. The unit is one of a group of physically similar packages from which a variety of computing systems can be constructed. The one in question forms the easy-access or computing store and is at present being used in the Pegasus computer.

Any system which possesses inherent time-lag can be made into a store. Briefly, the principles of this type of store are that pulses initiated at one end of the delay medium are received some time later. A store is formed by returning the received pulses, after amplification and shaping, to the input, where they are again propagated. Circulation progresses in this way until erasure is required when the circulating loop is broken. The capacity of such a store, say n digits, depends on the delay introduced, so that n times the digit separation is equal to the total delay time. To ensure correct timing, the delay must be an integral number of digits long, and some method of fixing the output in time must be used to give an output digit independent of slight variations in delay time. In general, variations in temperature affect the velocity of propagation and hence the delay time.

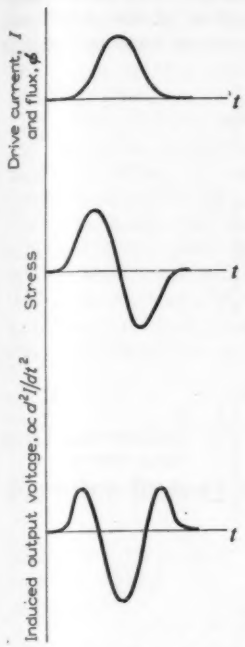
Fig. 1 shows the basic magnetostriction delay-line



1 *Sonic delay-line store*

store. Two small coils are threaded onto the ends of a length of pure nickel. By magnetostriction, the application of a current pulse to the drive coil results in the propagation of two equal stress waves travelling in opposite directions. One is absorbed by a soft rubbery termination while the other travels down the line with the speed of sound in nickel, i.e. at approximate velocity $\sqrt{(E/\rho)}$ (where E is Young's modulus and ρ is the density of nickel) and is received by an inverse magnetostrictive effect. To ensure that the transfer of magnetic energy to mechanical energy, and vice versa, is a maximum, the coils must be wound as close to the nickel as possible. The length and inductance of the coils are primarily dependent on the digit separation, and it is imperative that two consecutive digits can be resolved after reception. In this respect the problem is complicated by the distortion to which a longitudinal stress wave is subjected as it travels down the line. This results mainly from the increase of attenuation with frequency and to a lesser degree by bending the nickel to accommodate it in a practical system. For support, cellular polythene tubing has been found most suitable. Further distortion results from the flux penetration time at the driving coil. To keep this to a minimum, a bundle of nickel strip, which minimizes the eddy currents, is used. The effect of this distortion is to disperse the stress wave, which results

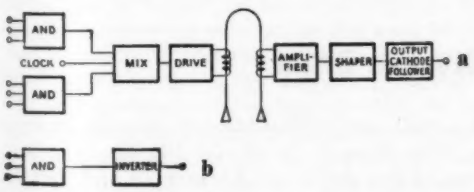
in consecutive digits running together. It is this which sets the limit on the maximum delay time, and hence storage capacity, for a given digit separation. The line under discussion is nowhere near this limit.



2 *Relationship between output voltage and drive current*

The output voltage is a function of the double differential of the drive current. One differential is associated with the relationship between drive current and stress, because a stress wave is propagated only when a change of drive current occurs. The other is associated with the relationship between stress and induced output voltage, output voltage being proportional to the rate of change of flux. This is illustrated in Fig. 2.

The block schematic in Fig. 3 shows the electronic apparatus associated with the line. The twin 'and' gate input is provided for decoding and line selection in the computer. The signal from the gate is fed to the grid of the driving valve, which switches a current of 12 mA through the drive coil in the anode circuit. After amplification a positive signal, suitably clipped, is pulse lengthened to a fixed time determined by a standard timing waveform, and produces a standard digit as used throughout the computer. Any variation in the timing of the signal due to temperature variation results in the corresponding variation in the width of the output digit, the back edge remaining fixed. As the standard procedure is to retime digit waveforms at the input of all the logical circuits, a variation of about 1 microsec in the width of the standard digit from a delay line can be tolerated. The inverter is used in conjunction with the input gate to open the circulating loop and erase the digits stored.



3 *Block schematic of associated electronic apparatus*
(*a*) Delay circuit. (*b*) Inverter.

In practice, the line is mounted on a sub-panel which plugs onto the side of a standard package. An adjustment of the drive coil with respect to the nickel is provided and can be made from the valve platform.

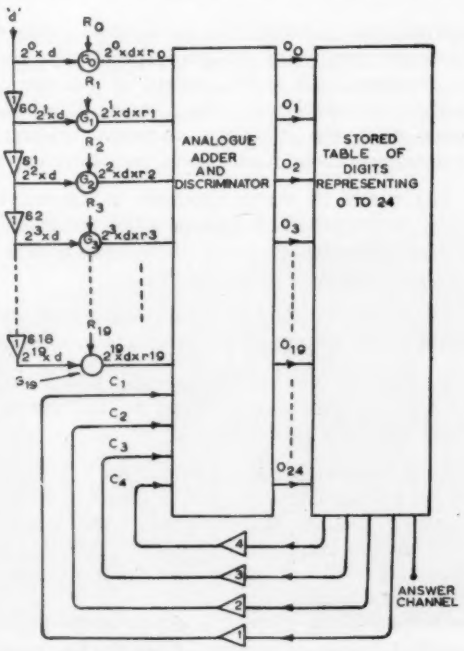
621.374.32 : 621.374.5

Multi-Input Adder

Paper No. 2078 entitled 'A Multi-Input Analogue Adder for Use in a Fast Binary Multiplier', by D. B. G. Edwards, Ph.D., M.Sc.

THE PAPER DESCRIBES THE DETAILED DESIGN AND OPERATION of an analogue adding system which has many input and output channels. When several of the input channels are simultaneously excited, an output indication is given on only one output channel, the particular one selected depending upon the total number of input channels excited at that time. In practice, any number of inputs ranging from 0 to 24 can be activated and these define a corresponding number of states within the circuit which are stable for the duration of the input excitation. The voltage difference between each state can be made relatively small, because the discriminators which identify the output indication are included within the feedback loop which defines these states.

The system was devised to operate in a binary multiplier the principle of which is shown in the diagram. One of the two numbers to be multiplied, for example the multiplier



Schematic of the multiplier

number r, is held on a staticizor which controls gates G_0 to G_{19} with the 'staticized' outputs R_0 to R_{19}. The multiplicand number d is fed to the other inputs of these gates, but via digit delays, so that the inputs correspond to $2^0 \times d$, $2^1 \times d$, etc. At the outputs of the gates the requisite sub-products $2^0 \times d \times r_0$, $2^1 \times d \times r_1$, . . . , are obtained and these are fed as inputs to the analogue adder. In any one digit period only one output channel will be excited, and this indication is used to look up a stored table of digit values. From this table the correct sum digit at that time, and any carry digits to subsequent digit periods, are obtained. The carry digits are connected via appropriate digit delays back to the carry inputs C_1 to C_4 of the adder. In this way all the sub-products are added to produce the final product. The multiplier will produce the product of a 20-digit and an n-digit number in approximately n digit periods.

The multiplier described is an economical one compared with other methods, but it has the disadvantage that close-tolerance components and voltage supplies have to be used if 24 discrete inputs are to be accommodated satisfactorily by the adder. 621.374.32 : 681.142

Transfer-Track Method

Paper No. 2081 entitled 'The Transfer-Track Method of Magnetic-Drum Operation', by J. E. Flood, Ph.D., Associate Member, R. S. Hopkins, B.Sc.(Eng.), Associate Member, and H. A. Showell, Graduate.

IN ADDITION TO GENERAL-PURPOSE DIGITAL COMPUTERS, machines are now being designed specifically for particular purposes, such as the control of machine tools, air traffic or telephone calls. These data-handling machines have the following common requirements which distinguish them from general-purpose computers:

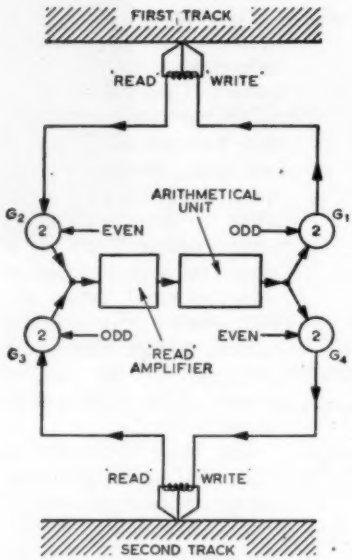
(*a*) The nature of the computation is simpler, being limited to the particular one for which the machine is designed. The predetermined programme is thus built into the machine.

(*b*) There may be many input and output stations each of which may require to use the machine at any time.

(*c*) Because the output often produces results in terms of money, materials, or service to the public, the circuits must 'fail to safety'.

In some data-handling machines the information is stored on a magnetic drum and is read out from each track, passed through an arithmetical circuit and written in again during every revolution. The authors explain previous methods of doing this, and discuss their advantage and limitations.

The transfer-track method is shown in the Figure. In this method, information is read from the first track and written into a second track, via an arithmetical circuit, on every other revolution of the drum. During the intervening revolutions the information is read from the second track and written into the first track via the same arithmetical unit. The construction of the drum and amplifiers used is simple, and only one head per track is



Transfer-track circulation scheme
G_1–G_4 are gates.

required. If the periodicity with which the stored information is required to be modified is less than that of the drum revolutions, one transfer track and arithmetical circuit can be shared by several storage tracks. The authors discuss relevant arithmetical processes and give details of practical reading, writing and switching circuits for use with the method.

621.374.32 : 621.395.625.3 : 681.142

Ace Storage Drum

Paper No. 2090 entitled 'The Magnetic Storage Drum on the Ace Pilot Model', by D. O. Clayden, Graduate, L. J. Page, B.Sc., and C. F. Osborne, A.M.I.Mech.E., Associate Member.

THE ACE PILOT MODEL AT THE NATIONAL PHYSICAL Laboratory is an electronic digital computer using mercury delay lines for its high-speed store. Eighteen delay lines, of various lengths, circulate pulse patterns representing about 11 500 binary digits at one million pulses per second. The magnetic drum, a cheaper form of digital store operating at one-ninth of this speed, stores a further 262 144 binary digits on 256 tracks.

The drum is 5 inches long, 4 inches in diameter, and revolves at 6 500 r.p.m. The recording medium is magnetic-oxide powder mixed with an epoxy resin to form a hard durable surface. The track spacing is

0·017 inch, and each track contains about 80 digits per inch.

Information is transferred between the drum store and its particular delay line in blocks of 1 024 digits, this being the capacity of each track and of the delay line. Each transfer takes about 12 millisec, including switching time.

The drum is driven by a synchronous hysteresis motor, and has to be synchronized to the computer with an angular accuracy of one digit spacing, or $\pm 10'$ of arc. The accuracy achieved is about $\pm 1'$ of arc.

For economy, the recording and reading heads are mounted so that they can be moved parallel to the axis of the drum, each head thus having access to sixteen tracks. In this way only sixteen pairs of heads and their amplifiers are required for the 256 tracks. The heads take up to 50 millisec to shift.

621.374.32 : 621.395.625.3 : 681.142

Parallel Operation

Paper No. 2108 entitled 'A Fast Parallel Arithmetic Unit', by K. D. Tocher, B.Sc., Ph.D., and M. Lehman, B.Sc., Associate Member.

THE NEED FOR EVER-INCREASING OPERATING SPEEDS FROM digital computers will, in the future, result in the more extensive use of parallel techniques, particularly in the computing or arithmetical sections of such machines. Parallel operation implies the simultaneous handling, in separate channels, of all the digits of a number, whereas in serial operation these digits are operated upon successively in only one channel. The change to parallel operation requires the application of quite different techniques in logical and engineering design. The paper outlines some of the main points that must be considered and the problems that result, and shows how these have been solved in the design for one particular machine ICCE II, the arithmetic section of which has been built in the Mathematics Department of Imperial College.

Of various alternatives available, the method of addition adopted is one in which the digits of one number, and any carries, are counted into the corresponding digits of the other number. In the binary number representation adopted, this simply requires the conditional complementing of the digits of one operand from the corresponding digit of the other, and from any carries coming into each stage. An innovation, made possible because of the simple nature of the carry function in binary arithmetic, is that the carry digit may be added into (i.e. used to control a conditional complementing of) the addend register, before the digit which is to be added to it is counted in. This means that no temporary storage is required for the carry digit.

After discussing the possible representation of negative numbers in the machine, the paper considers the elements required by the arithmetic units, and in particular the alternatives which arise for the design of a carry computer. The chief requirement in this element is the minimization of possible carry propagation times, which arises when the *carry out* from any one digit stage is a function of earlier digit stages.

The arithmetic unit is then described in detail, and an outline given of how the various operations required are performed. Circuit descriptions are given of the packages from which the units and the machine are built, and these are followed by an outline of the asynchronous control associated with this arithmetic unit.

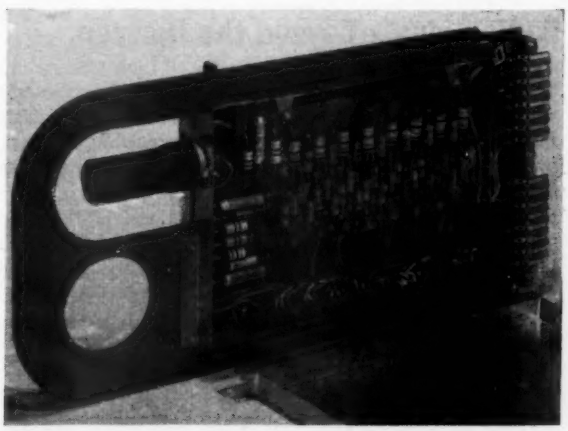
The performance details, speed in particular, by which a machine may be judged, are the times taken for the solving of a variety of real mathematical problems. As such figures are not available, a conception of machine speed may be given in terms of basic operation times, and the type of code used. Thus, for example, the addition time is less than 4 microsec, and the shift time per digit 1·2 microsec (sequential in multiplication and division). It is, however, pointed out that the logical circuit conceptions outlined will find application in even faster machines, the limitation in ICCE being mainly due to financial difficulties of the group building the machine.

681.142

Store Used in Pegasus

Paper No. 2169 entitled 'The Magnetic-Drum Store of the Computer Pegasus', by I. W. Merry, B.Sc.(Eng.), Graduate, and B. G. Maudsley, A.M.I.Mech.E.

THE MAIN STORE OF THE PEGASUS COMPUTER IS USED TO hold (i) the data on which calculations are to take place, (ii) the programme of orders which control the nature of the calculations, (iii) a more or less permanent set of orders used during the input and assembly of programmes and data, and (iv) a set of test routines by



Write/read switch package used in Pegasus

which the reliability of the computer may be checked and fault tracing facilitated.

Storage of these items is effected by means of a magnetic drum which is in essence a cylinder coated with magnetic iron oxide (γFe_2O_3) in an epoxy resin paint, rotating at 3720 r.p.m. in a very-high-precision bearing assembly that runs with an eccentricity of less than 0·0002 inch. Information is recorded as groups of 42 pulses by a number of ferrite recording heads mounted in blocks of ten, similar to those used in other applications of magnetic recording. The recording heads are subsequently used as reading heads to recover stored information, which leads to economy of manufacture and simplicity of design, since mechanical alignment troubles are reduced.

The information recorded by any particular head is stored around a narrow track on the drum surface. Electronic cross-bar or matrix switches are used to select particular tracks as they are required, a track being specified by row and column numbers of an 8×5 matrix. Separate packages, of the type shown in the photograph, are used for each column of the switches. Track selection on reading occurs in balanced diode gates prior to amplification. Considerable economy in electronic requirements is achieved by this method.

681.142

SYNOPSES OF PAPERS

The following are synopses of papers published in the *Proceedings* without first being read at an Institution meeting which have not been described elsewhere in the *Journal*. Another such synopsis (of paper No. 2185 by M. H. N. Potok) appears on p. 676.

Transmitter Linearity

A synopsis of a Radio and Telecommunication Section paper (No. 2171) entitled 'An Experimental Assessment of the Linearity of a V.H.F. Transmitter', by D. E. Hampton, B.Sc. The paper is published this month in Part B of the Proceedings.

AN EXPERIMENTAL PROCEDURE IS DESCRIBED FOR TESTING the assumption that a generator behaves as a linear source.

The source admittance is obtained from measurements made when the generator is operating normally, and the problem is considered of matching this source admittance to the characteristic admittance of the feeder connecting it to a wide-band aerial. 621.396.61

Radio Signals Beyond the Horizon

A synopsis of a Radio and Telecommunication Section paper (No. 2186) entitled 'Some Aircraft Measurements of Beyond-the-Horizon Propagation Phenomena at 91·3 Mc/s', by B. J. Starkey, Dipl.Ing., Associate Member. The paper is published this month in Part B of the Proceedings.

FIELD-STRENGTH MEASUREMENTS AT DISTANCES EXTENDING far beyond the horizon from a transmitter on a frequency of 91·3 Mc/s have been carried out in an aircraft flying at a height of 10000 ft.

The analysis of the results obtained and their correlation with meteorological data suggest that many phenomena of long-distance propagation could possibly be explained by the simple hypothesis of specular reflection from temperature-inversion layers at the tropopause.

621.396.11

Atmospherics at Low Frequencies

A synopsis of a Radio and Telecommunication Section paper (No. 2147) entitled 'An Investigation of Atmospheric Radio Noise at Very Low Frequencies', by F. Horner, M.Sc., Associate Member, and J. Harwood, M.A., Ph.D. The paper is published this month in Part B of the Proceedings.

A DESCRIPTION IS GIVEN OF A TECHNIQUE FOR INVESTIGATING the characteristics of atmospheric noise.

Atmospheric noise in a bandwidth of 300 c/s at frequencies in the range 10–35 kc/s is intermediate in character between fluctuation noise and discrete impulses. For example, the variation of the average voltage with bandwidth is similar to that for fluctuation noise, but the noise also contains peaks of high amplitude. The r.m.s. value of the envelope is of the order of five times the average value, which illustrates the impulsive nature of the noise and shows that neither parameter by itself can provide a satisfactory description of the noise. The long-term trends, however, have been expressed in terms of the average field strength.

A more detailed description of the noise is given in terms of the amplitude distribution of the peaks in the envelope and the amplitude probability distribution of the envelope itself. Either of these distributions can be expressed empirically in terms of two parameters, and both can be interrelated at the higher voltage levels where the impulses have consistent shape determined by the characteristics of the receiver.

It has been found that the larger impulses are randomly distributed in time. There is a tendency for the smaller impulses to occur in groups, but it is doubtful whether the slight departure from randomness would have a significant effect on the severity of the interference with the usual types of radio service. 621.396.822

Calder Hall

Opening by H.M. the Queen

On the 17th October Her Majesty the Queen formally opened the world's first full-scale nuclear power station at Calder Hall. It was an event of profound significance to the economy of the country. A brief description of the plant is given here as a preface to the B.N.E.C. Symposium to be held on the 22nd and 23rd November at the Central Hall, Westminster.

Above a lakeland stream looms a Wellsian silhouette

THE designing and building of Calder Hall in three and a half years, with all its novel problems and exacting specifications, is an achievement by any standards, and the ceremonial opening by the Queen was a tribute to the devoted work and exceptional skill of the scientists and engineers who performed this feat.

Situated in a lonely part of the Cumbrian coast, just clear of the wild hills and moors of the Lake District, Calder Hall provides a dramatic contrast between the old placid rural life and the industrial world of giant machines, between the age-old culture of the soil and the fierce struggle for economic survival. Amid a landscape of rich pastures and rambling stone walls, of grey hamlets and narrow lanes along which shepherds drive flocks of sheep, the gleaming conical cooling towers and long low turbine hall stand remote and solitary, connected to their industrial cousins only by the slender pylons that stalk away across the fields into the hazy distance. One cannot quite believe in the reality of the power station until one stands in the shadow of the reactor building and hears the powerful hum of the blowers. Yet so still and clean is the plant, so free from the dirt and noise of the factory that it seems to blend itself with the hills and mists, as if industry had learned a lesson in pastoral philosophy.

The difference between a conventional station and Calder Hall is the difference between a horse-drawn carriage and an early motor car. The source of power has been revolutionized but the remainder is much the same. The turbine hall and switchgear are like those of any orthodox medium-power generating station, and the most conservative supply engineer would feel thoroughly at ease with them. It is when one steps outside to the great reactor houses with their complicated heat exchangers that one is in unfamiliar surroundings.

The reactor itself is a cylinder of pure graphite 27 ft high and 37 ft in diameter containing 1 696 vertical channels for the fuel rods and 106 vertical channels for the control rods. The graphite core fits into a cylindrical pressure vessel with domed ends, made of 2-inch-thick mild steel. In the fuel channels are suspended 10 176 natural-uranium rods in magnesium-alloy cans equipped with helical fins. When the control rods are withdrawn the temperature of the uranium rises, but it is maintained at 400° C by a stream of carbon-dioxide cooling gas, which flows upwards through the vertical channels in the annular space between the cans and the graphite. The gas is kept at a pressure of 100 lb/inch^2, entering at the bottom with a temperature of 140° C, and emerging from the top at a temperature of 336° C.

The pressure vessel is housed in an octagonal concrete *biological* shield 7 ft thick at the sides and 8 ft thick on top, lined with a 6-inch-thick steel plate for protection against thermal neutrons. The outside of the pressure vessel is additionally cooled by air which enters the bottom of the biological shield from the atmosphere and is discharged from two steel chimneys above the reactor house. The hot carbon-dioxide gas from the pressure vessel is conducted to four heat exchangers, which are crossed by a large number of steam pipes having a total surface area of almost 100 000 ft^2. Each heat exchanger generates high- and low-pressure steam simultaneously, the former at 200 lb/inch^2 and 310° C and the latter at 53 lb/inch^2 and 171° C, as delivered at the turbine stop valve. After passage through the turbine blades the steam is condensed by water from the cooling towers, and is pumped back to the heat exchanger.

A point of interest to electrical engineers lies in the

The Queen looks round

Mr. H. G. Davey, Works General Manager of the Northern Area, Atomic Energy Authority, escorts Her Majesty on a tour of Calder Hall. The picture shows them inspecting the blower house.

provision in the turbine hall of a *dump* condenser. The purpose of this is to absorb heat from the reactor if this exceeds the maximum capacity of the turbines, and to 'dump' the steam which the reactor continues to raise for 28 hours after shut-down, for the reactor cannot be cooled as rapidly as a normal coal-fired furnace without possible damage to the fuel elements.

The pressures and temperatures generated by the heat exchangers are much lower than in a conventional power station because the temperature of the uranium rods must not be allowed to exceed 400°C, beyond which temperature there is a danger that the uranium metal will undergo an unusual expansion. Consequently the thermal efficiency of the power station is only about 25%.

The Calder Hall plant at present in operation consists of two reactors in separate houses, eight heat exchangers, eight main blowers, four turbo-alternators and condensers, two dump condensers and two cooling towers. The alternators deliver a maximum power of 23 MW at a power factor of 0·8 and a voltage of 11·5 kV, but the maximum efficiency, with the turbine blades set at their present angle, is at 21 MW. Thus the four alternators supply 84 MW to the Grid. The plant itself and the adjacent Windscale plant draw their power from the Grid, and although their requirement has not been revealed, it has been stated to be considerably less than the output of Calder Hall, so that there is a net surplus.

Another power station of duplicate design is being constructed on the same site, and the twin stations are designated Calder Hall 'A' and Calder Hall 'B', the latter being practically a mirror image of the former, and the equipment being similar in all respects.

It may be asked why Britain has built a nuclear power station at this early stage, when future designs may prove to be cheaper and more efficient. The reason is partly that Britain urgently needs other sources of energy, and the natural-uranium graphite-moderated gas-cooled reactor was known from experience at Harwell and Windscale to be practicable and free from many of the problems of more ambitious reactors, and partly because another reactor was needed anyway for the production of plutonium for military and civil purposes. Indeed, plutonium production was the primary aim of Calder Hall, but it was thought that the heat of the reaction could well be used to generate electricity instead of being discharged uselessly into the air as at Windscale. In addition to the construction of Calder Hall 'B', two similar reactors are to be built at Chapel Cross to increase the supply of plutonium. The first reactors to be built for the Central Electricity Authority under the Government's ten-year programme will also be of the Calder Hall type, because it is still the only type which is really known to be a commercial proposition.

Years of careful investigation have proved that gas-cooled nuclear power stations involve no health hazard in the surrounding district. No special safety zones are required, and although at first stations will be built in rural areas by Government policy there is no reason why they should not eventually be built in the middle of large cities.

The cost of Calder Hall was £16½ million, and, since its output will be 92 MW by the spring of next year, this is equivalent to £180/kW, compared with about £55/kW for a 200 MW conventional station. With the experience gained, however, the cost of future nuclear power stations should be much less. This is because metallurgical research indicates that the uranium could be run at a higher temperature and because developments in welding will permit the making of spherical pressure vessels of twice the thickness of steel plate used in the Calder Hall reactor. Such advances will enable future gas-cooled power stations to be built with higher efficiencies and

much greater capacities than was thought possible.

In spite of the first cautious estimates it is now apparent that nuclear fuels are already able to compete on fairly equal terms with fossil fuels. The deciding factor is the length of time which the uranium rods can be left in the pile before the activity seriously decays through the accumulation of fission-product impurities. This will finally be found by operating experience, but an official estimate is 3000 MW-days per tonne of uranium. On the assumption that this figure is correct, the cost of electricity generated at Calder Hall has been stated to be roughly 0·6d./kWh. If, however, a credit of 0·27d./kWh is allowed for the plutonium produced, the cost is only 0·33d./kWh, compared with 0·53d./kWh for coal-fired plant. The allowance of a credit for the plutonium is not an artificial concept because this fissile material may well be used in future reactors, with a consequent saving of uranium.

Fission to factory

Power from the reactor in the centre is fed into the Grid. The architecture of the entrance gate and the workshop/administration building (behind the power transformers) makes use of local stone.

These tentative figures show that nuclear energy, even in its present state, is an economic source of power, capable of competing with coal and oil without the aid of Government crutches. There are strong hopes that future development and the introduction of more advanced, enriched reactors will lower the cost of electricity still further. In ten years' time the building of coal- and oil-fired stations will cease altogether, and it is hoped that by the end of the century none will be left. For the next few decades, however, until nuclear generation is able to supply the major load, coal will be needed as much as ever. Thereafter it can be used where it is most valuable—in the chemical industry. So rich is coal in basic organic chemicals that burning it is really the most wasteful crime we can commit.

Thus the promise of Calder Hall is of an increasingly abundant and ever cheaper supply of electricity, which will raise our industrial potential, improve our standard of living, purify our cities and, one hopes, make us independent of fuel from politically unstable areas.

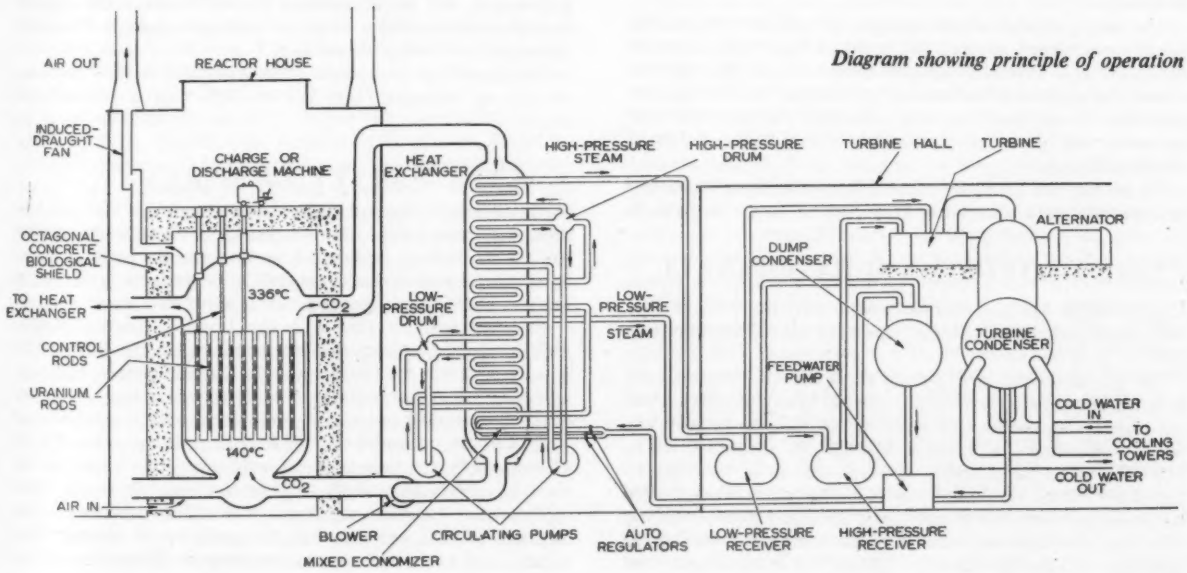


Diagram showing principle of operation

OBITUARY

FREDERICK CARLETON ANDERSON

Frederick Carleton Anderson, who died suddenly on the 8th June 1956, was born on the 28th December 1875. He was educated at Glasgow Academy, at the High School, Napier, New Zealand, and at Real Gymnasium, Stuttgart, Germany. He received his technical education at the Royal Technical College, Glasgow, gaining the diploma of the college in 1893, and obtained practical experience with Denny and Co., marine engineers, at Dumbarton. The first four years of his working career were spent on the staff of Selby Bigge and Co., electrical contractors and consulting engineers. In 1903 he went into business on his own account with Mr. C. Atherton Atchley and the late Mr. G. Harland Bowden to form the original partnership which became the Harland Engineering Co. During the period up to 1919 the company concentrated on electrical power contracting, and the rapid expansion of the business was centred upon schemes of complete electrification (sometimes including provision of thermal generating plant) in textile- and paper-mills, steel works, mines and other industrial undertakings. Certain types of switchgear were by then being manufactured in Manchester under Mr. Anderson's direction. Subsequent to the acquisition by Harland of the Alloa Works, where centrifugal pumping plant and electrical rotating machinery were manufactured, Mr. Anderson continued to play a leading part in the development of sales in the large industrial areas of Lancashire, Yorkshire and the north-east coast, and he also did much of the pioneering work abroad leading to the widespread application of sectional electric drives for paper-making machines in Europe and Canada. Until shortly before his retirement in 1952 from the position of Chairman of the company, he resided near Manchester. He was a Past-President of the Manchester Association of Engineers, a member of the Manchester Geological and Mining Society, and a member of the Association of Mining Electrical Engineers.

The characteristics which were prominent throughout Mr. Anderson's career can be epitomized in the words integrity, prudence and loyalty. He was possessed of an absolute honesty of purpose which made him incapable of the slightest questionable action of any kind. His opinions were wise and valuable, and he was always understanding in the matter of human relations.

He joined The Institution as an Associate Member in 1909 and was elected a Member in 1929. K. W. A.

CYRIL GEORGE MANCHA BENNETT

Cyril George Mancha Bennett, who died on the 5th July 1956 after a six-month illness, was born on the 1st February 1875.

He was educated at Clapham High School, Bruce Castle School, Tottenham, and Clewer House, Windsor, and started his engineering career as a pupil at the Thames Iron Works and Shipbuilding Co., Blackwall, under Mr. Arnold F. Hills. For two years he attended evening classes at the City of London College. On completion of his apprenticeship in 1896 he joined the Kensington and Knightsbridge Electric Lighting Co. as an assistant engineer. When this company collaborated with the Notting Hill Electric Lighting Co. in erecting a joint power station at Wood Lane, he was appointed engineer on site and had complete charge of the civil, mechanical and electrical equipment, with the design of which he was also closely concerned. On completion of the station he was appointed Resident Engineer, eventually becoming Chief Engineer to the joint companies, in which capacity he designed and supervised the construction of the second station on the same site.

When Wood Lane power station was taken over by the London Power Co. in 1927 he was appointed Chief Control Engineer and was responsible for the development of their central control system, including the design of a control diagram incorporating many novel features. He held this position until he retired from the industry in 1945.

Owing to his practical training he was (as was frequently the case with engineers trained under the old pupilage system) a first-class craftsman, and he put this to great use by personally making models of a large number of inventions with which he was associated. He started taking out patents as early as 1902 and continued patenting many ingenious devices up to the end of his life. One of his most successful inventions was a locking ring for preventing unauthorized removal of electric lamps from their holders. This was patented in 1918, when Mr. Bennett formed the firm of Lamlok Ltd., for the manufacture of this and similar devices.

Mr. Bennett was an engineer of the old school and was always immaculately dressed, and it might be of interest to younger engineers to know that he went to the interview for his first post correctly dressed, for that period, in top hat and morning coat.

A widely read man, interested in many activities outside his normal professional duties, Mancha Bennett had the ability to engender in all who worked under him an enthusiasm equal to his own. This gift was in the main due to his friendly and courteous personality, keen sense of humour and quickness of mind, which made him such a delightful person to work for; and he will be remembered for many years with admiration and affection by a large circle of colleagues and friends. He leaves a widow and one son.

He joined The Institution as an Associate in 1899 and was elected as Associate Member in 1909 and a Member in 1920. E. B. P.

WALTER HARVEY CHAPMAN

Walter Harvey Chapman, who died suddenly on the 2nd July 1956, was born on the 29th August 1876. He was educated at St. Paul's School, and, after a few months with Messrs. Spagnoletti and Crookes in 1893, he became a full-time student at Finsbury Technical College for two years.

He then spent a year with the London Electric Supply Corporation and joined the Metropolitan Electric Supply Co. in January 1897. By 1905 he was the Superintendent in charge of operation and construction work at the company's Tower Street substation, which at that time had a capacity of 4000 kW. He married in 1909 and took up residence in Greenford, where he remained for thirteen years, subsequently moving to Northwood. In 1910 he was engaged in the company's area lying to the west of London comprising the districts of Hanwell, Southall, Greenford and subsequently Acton, and was closely associated with the Thury d.c. system

operating between the generating station at Acton Lane, Willesden, and the substation at Ironbridge, Southall, under Mr. J. S. Highfield, then Chief Engineer.

Later Mr. Chapman became the District Superintendent of the West London district and maintained his association with these areas for some years. At the time of his retirement at the beginning of 1940 he was Senior Engineer in the London area of the company, having held that position for some ten years, together with other special assignments from time to time.

After his retirement he joined the Westminster Engineering Co. as Assistant Manager and remained with them until 1949. He is survived by his widow.

His activities were widespread, embracing the electricity supply industry from the engineering to the commercial side, and included many special investigations for the management of the company, for which he was well adapted by virtue of his long experience and versatility.

Mr. Chapman joined The Institution as a Student in 1895 and was elected an Associate in 1898, an Associate Member in 1906 and a Member in 1916. E. C. T. O.

JAMES HERBERT EDWARDS

James Herbert Edwards, O.B.E., who died suddenly on the 22nd June 1956, was born in 1872. He was educated at Wycliffe College, Stonehouse, at Cardiff University College and at Faraday House, and became a pioneer of electricity supply in small towns at the beginning of the century, and later a pioneer of rural electrification.

He obtained his practical training with the Taff Vale Railway engineering works, then with the Newport electricity works and finally with the Blackpool electricity works; he began his career in 1895 as an assistant engineer at the Cardiff Corporation electric generating station. A year later he spent a short time as an assistant in the standardizing room at Faraday House, but quitted this in three months to become the junior partner in the firm of Kingsland and Edwards of Llandudno. The work of the firm consisted chiefly in the installation of complete isolated electrical plant for large hotels and private country houses. When the partnership ended in 1899 he became the senior partner in the firm of Edwards and Armstrong. The office and works were situated at Bristol, and branches were opened in Cardiff, Ludlow, Chippenham, Tewkesbury and Dulverton.

The firm installed the first electric lighting installations in the City Hall, Cardiff, and Colston Hall, Bristol. Statutory orders were granted to the many electricity supply companies which Mr. Edwards established from 1900 onwards. He formed the Wessex Electricity Supply Co. and initiated the 1927 and 1928 Wessex Electricity Acts, which were concerned with an area of approximately 4000 sq. miles. At Vesting Date, 20 years later, the company had over 5000 miles of main networks, 165 000 consumers, and a maximum demand of 135 MW.

Mr. Edwards was a man of fine physique and personality, possessing exceptional gifts as an engineer, administrator and financier, and yet withal his disposition was quiet, shy and unassuming. Students articled to him remember particularly his kindliness and marked facility for delegating responsibility to the lowest reasonable level, junior engineers and apprentices being permitted, and expected, to show a surprising degree of initiative and self-reliance and to make decisions. His foresight and interest in technical education were shown when he introduced to his companies, as long ago as 1920, a system of day release for apprentices to attend technical colleges. Mr. Edwards had been Chairman of the Board of Governors of Wycliffe College for the past twenty-three years, and Chairman of the Cranham Parish Council for thirty-three years. He was made an O.B.E. for his services to the National Savings Association during the First World War. His wife died twelve years ago and there were no children.

Amongst his many acts of philanthropy were gifts, including land and buildings, to the Boy Scout movement, for which he was presented with the Thanks Badge by Lord Baden-Powell.

He was a kindly man of high principles and simple tastes, who will be remembered with respect and affection by the many engineers who worked with and for him in the difficult and strenuous pioneering days of public electricity supply.

He joined The Institution as an Associate Member in 1910 and was elected a Member in 1913. K. L. M.

OSCAR FABER

Oscar Faber, C.B.E., D.C.L.(HON.), D.SC.(ENG.), F.C.G.I., who died on the 7th May 1956, was born on the 5th July 1886. His death removes from the engineering world one of the outstanding personalities of these times.

He was educated at St. Dunstan's College, Catford, and at the City and Guilds College, South Kensington, where in 1906 he obtained a B.Sc.(Eng.) degree and later he was elected an F.C.G.I. He was an 'all-rounder' in engineering, and, on leaving college, he joined the Associated Portland Cement Manufacturers. While with this firm he wrote a thesis on the engineering problems of reinforced concrete, a technology then in its infancy. For this work he was awarded his doctorate in engineering, and lived to see his name universally acknowledged as a pioneer in this field.

In 1909 he became an assistant engineer with the Indented Bar and Concrete Engineering Co., and two years later he was appointed Chief Engineer with Trollope and Colls, London, with whom he stayed until 1920. He then started in practice as a Consulting Engineer, and in 1948 became the senior partner in the firm of Oscar Faber and Partners.

His work covered a varied field. He was interested in heating and ventilating engineering, and for a paper on the heat pump he was awarded the George Stephenson plaque by The Institution of Mechanical Engineers.

In electrical engineering he was much attracted to the economies resulting from the combination of electrical generation with heat production, and, of the numerous installations which he designed on this principle, that at the Bank of England is best known. Here he introduced many features which at the time were novel, but which later became common practice. Similarly, in illumination, he was not content with the types of fitting available at the time and set about working out designs of his own, several of which are still in use for the lighting of bank and office buildings.

He was made an O.B.E. for his work in the 1914–18 War and a C.B.E. in connection with the rebuilding of the House of Commons in 1946. He was also awarded an honorary D.C.L. by the University of Durham for his enterprise over the preservation of Durham Castle.

He possessed that type of keenly analytical brain which, presented with a set of facts, could single out almost by intuition the one essential point which had escaped many who had perhaps studied the matter for weeks. He hated anything complicated; he distrusted a ready-made formula, or a stock answer that he did not understand. His numerous books and

papers all reveal this directness of approach; his famous paper on the plastic yield of concrete, for instance, which opened up entirely new ground, was based on the simplest of tests which he himself carried out.

In his private life, Faber was equally a man of simple tastes. He loved his family, his home, his garden, his water-colour painting and his music. In music he was especially gifted. He had a pleasing tenor voice, and would play the piano by the hour; he composed music and he played the organ, the oboe and the clarinet. At one time he entered the Royal Academy of Music and had thought of taking up the vocation professionally. Wagner's 'Ring' at Covent Garden was an annual engagement for which all appointments must be set aside.

His capacity for work he retained to the end. It would appal anyone who did not know him. In his numerous foreign travels to jobs in all parts of the world he never spared himself. After a long, tiring journey by air to some distant outpost he would, as likely as not, at once accept an invitation to lecture to the local engineering society.

He leaves a widow, two daughters and a son, who is a partner in his father's firm.

So passes a towering figure of a man, unique, original, in many ways a genius—one who, in a long life, had innumerable friends, though there were those who did not agree with him. Yet all who had any kind of contact with him would say that the world is the poorer through his loss.

Dr. Faber joined The Institution as a Student in 1905 and was elected an Associate Member in 1911 and a Member in 1955. He was also a Member of The Institutions of Civil and of Mechanical Engineers, and a Past-President of The Institutions of Structural Engineers and of Heating and Ventilating Engineers. J. R. K.

DAVID GOAD

David Goad, O.B.E., who died on the 7th July 1956, was born on the 3rd June 1880. He received his early technical education at the Regent Street and Northampton Polytechnics, and began his career with Drake and Gorham, London, in 1896 as a junior draughtsman working on the design of switchgear, arc lamps and accumulators. After three years with this firm he joined A. V. Gifkins and Co., London (consulting engineers), as Outside Constructional Engineer, in which capacity he worked on lighting, power, refrigeration, and pumping plant. In 1903, four years after joining the firm, he was appointed Manager, in 1910 he became a Partner, and when the firm became a limited company in 1914 he became a Director. He represented his firm in India from 1913 to 1917, supervising lighting and power schemes.

In 1917 he was commissioned as a Lieutenant in the Royal Naval Volunteer Reserve, and served in the Air Service Constructional Corps. He was transferred to the newly formed Royal Air Force in 1918, with the rank of Major, and served as Head of the Mechanical and Electrical Section of the Air Constructional Service. For this work he was made an O.B.E. in 1919.

In 1920 he became a Superintending Civil Engineer in the newly formed Air Ministry Directorate of Works and Buildings, and in 1928 he was appointed Chief Mechanical and Electrical Engineer, in which capacity he served with distinction until his retirement in 1942. After his retirement his services were retained by the Air Ministry in a consultative capacity until 1945 as Adviser on Mechanical and Electrical Services.

Major Goad joined The Institution as an Associate Member in 1912 and was elected a Member in 1920. A. W.

MAURICE GEORGE HAMMETT

Maurice George Hammett, who died on the 7th May 1956, was born on the 28th January 1907. He was educated at Kirkdale Road School, Leytonstone, and afterwards took a four-year engineering course at Leyton Technical College. He obtained practical experience with the Sterling Telephone and Electric Co. at Dagenham from 1923 to 1927, and then moved to The Gramophone Co. After a short period in an experimental workshop, he was transferred to the Recording Division of the company, and remained on recording work for five years, during which time he took part in a number of recording expeditions in Europe and the Near East. In 1933 he was transferred to the Test Gear Development Department. In the early nineteen-forties he undertook a number of development projects on predictors and similar devices in connection with the company's increasing war effort, and thereafter he was almost entirely engaged on this type of work, until he resigned in 1948 to join E. K. Cole, at Malmesbury, with whom he remained for approximately five years.

In 1953 he became Chief Engineer of the Electronics Division of Murphy Radio. With this firm, until his death, he was largely engaged on development work in radiocommunication and secondary radar, but he also carried out work on a wired television system, and supervised the rapid engineering design and manufacture of a number of colour-television receivers, for the demonstration of an experimental colour system.

He was a man of exceptional force and individuality of character. In his younger days this sometimes tended to express itself in unconventional dress and a certain reluctance to 'suffer fools gladly'. But he made many friends, and as he grew older these external symptoms fell from him, as did some of his restless energy, but he retained to the last his outstanding and uncompromising intellectual honesty.

During the last years of his life he suffered increasingly from the physical disabilities which led to his early death, but this did not prevent him carrying on a mass of valuable work. He leaves a widow and family.

Mr. Hammett joined The Institution as an Associate in 1948 and was elected an Associate Member in 1949 and a Member in 1952. C. S. A.

ROBERT HEATH

Robert Heath, who died on the 24th November 1955, was born on the 5th January 1897. He attended Felsted School, Essex, and the Regent Street Polytechnic. His technical education was interrupted by the 1914–18 War, and he resumed his engineering studies at Faraday House engineering college in 1919. He received his practical training at F. and A. Parkinson, Guiseley, and at A. Reyrolle and Co., Hebburn-on-Tyne, from 1921 to 1922, when he obtained the Faraday House Diploma.

At the end of his training he was appointed an assistant engineer at A. Reyrolle and Co., with whom he stayed for ten years, supervising outside construction work first in England and then, from 1927 onwards, in India. From 1930 he had complete control of the company's Calcutta office and acted as their sales representative in India.

In 1933 he joined the Punjab Government Electricity Branch, at Lahore, as Power Controller and Senior Sub-

station Engineer on the Uhl River project. The whole of the plant, which included five 132 kV substations with 200 miles of double-circuit line, eight 66 kV substations with 150 miles of line, and many smaller substations and associated plant, was tested and commissioned by him.

After the partition of the country in 1947 he was promoted to Superintending Engineer in charge of the rehabilitation of many Punjab power stations, which had suffered from neglect during the civil and economic upheaval. Before he left the Electricity Branch in 1953 he was appointed Resident Engineer at Shahdara Power Station near Lahore. His eventual retirement was a matter of regret to those engineers who were associated with him in the Punjab.

Mr. Heath continued to work in West Pakistan until his death. Shortly after his retirement he was employed by the Thal Development Authority, and was associated with the construction of power stations and textile mills. Later he joined the staff of the Fauji Textile Mill at Kala, near Jhelum.

He joined The Institution as an Associate Member in 1927 and was elected a Member in 1937. A. E. C. G.

ERNEST ALEXANDER LAIDLAW

Ernest Alexander Laidlaw, who died on the 26th April 1956, was born on the 21st May 1873. In 1889 he became an apprentice in the Western Counties and South Wales Telephone Co., which in 1892 was absorbed by the National Telephone Co. He undertook the installation of the first central-battery exchange for the National Telephone Co., and afterwards at the company's head office he supervised under Mr. (later Sir) Frank Gill the provision of central-battery equipment throughout the country.

In 1910, the year preceding the transfer of the National Telephone Co. to the Post Office, Siemens Brothers decided to take up the manufacture of telephone-exchange equipment, and Mr. Laidlaw was invited to join them as Chief Engineer and Manager in charge of the new venture. At this time opinions were widely divided on the possibilities and economy of automatic exchanges. With his unerring foresight, Mr. Laidlaw supported the new principle unreservedly.

Although hampered by the 1914–18 War he proceeded, after the successful installation of Port Adelaide, Grimsby and Stockport exchanges, with the development of the Siemens No. 16 system, which is still giving useful service in many parts of the world. He was always enthusiastic about the export market, and visited Chile, Brazil, Canada, South Africa, Egypt, Italy and Greece. As a result of his efforts many of these countries installed their first automatic exchanges.

Long before the conversion of the London network to automatic exchanges was actively planned, he read a paper before The Institution entitled 'The Telephone Service of Large Cities', which outlined a proposal for the application of the automatic system, and displayed convincingly the impossibility of continuing to provide service manually. Under his guidance the cam-type automatic telephone dial was developed; also the relay which was the basis of the present Post Office 3000-type relay, and the first telephone instrument using a handset adapted to the British central-battery and automatic systems—probably the only innovation in the telephone system to earn the favourable comments of *Punch*.

Prior to the Second World War he had turned his attention to the mechanization of long-distance traffic. One of the earliest patents in voice-frequency signalling was his. Semi-automatic cordless trunk switchboards developed by his company were installed in Cape Town and Melbourne, and have been widely adopted in Australia, Canada and South Africa.

He retired from Siemens Brothers in September 1942. Although he enjoyed the quiet of his cottage and garden on the banks of the Avon near Christchurch, his lively interest in telephone matters continued. Indeed, it was the intense interest he took in what was being done under his direction and in the men who were doing it that was always his outstanding characteristic. Undeviatingly loyal himself, he won the loyalty and the affection of all who worked with him.

Mr. Laidlaw joined The Institution as an Associate Member in 1907 and was elected a Member in 1912. His paper mentioned above, which was written jointly with Mr. W. H. Grinsted, was published in the *Journal* in 1919. He was awarded the Fahie Premium in 1920. W. H. G.

FRANCIS WALTER MAIN

Francis Walter Main, who died on the 1st June 1956, was born on the 31st May 1886. He was educated at Highbury New Park College and at Paradise House School, and received his technical education at Finsbury Technical College during the time of Silvanus P. Thompson.

He entered the employment of Johnson and Phillips, where for more than twenty years he was engaged in the development and production of all classes of electric cable.

In 1928 he joined Enfield Cables Ltd., Brimsdown, as Head of the Test and Research Department, and was appointed to the Board as Technical Director in January 1943. He resigned from his technical duties in February 1949, but continued as a director until December 1952, when he retired owing to ill health.

For the greater part of fifty years Mr. Main was associated with the cable industry; he was a leading figure in the technical field of electrical transmission by cables. He witnessed and took part in many notable advances and achievements in this field, and assisted in a major way in the advancement of the use of the paper-insulated cable from 11 kV to 300 kV. He was responsible for the development in Great Britain of compression cable design, which resulted in 1932 in the installation of the first cable in the world to use gas pressure —a 66 kV pipeline compression cable installed at Hackney, London.

For a number of years Mr. Main was a lecturer and demonstrator at evening classes in electrical engineering at the Woolwich Polytechnic, and will, no doubt, be remembered by many of his old students in the cable industry.

He was a person of sound religious principles, of cheerful disposition, and was well liked and respected by all with whom he came into contact. He was always willing to pass on his extensive cable knowledge to his colleagues and friends, by whom he will be sadly missed.

Mr. Main also had a great gift for entertaining, which would have graced a professional artiste. He could always be relied upon to give his services at concerts and social gatherings. It was fascinating to watch an impromptu performance by him, in which, with the minimum amount of equipment, he held an audience. He was also talented musically, and frequently played the organ at church. He was extremely fond of tennis and billiards and was a keen motorist, but his favourite hobby was the solving of mathematical problems. He leaves a widow.

He was, for many years, a member of several committees

in the cable industry and associated institutions. He made many written contributions relating principally to the cable industry, and wrote a book entitled 'Electric Cables', the first edition of which was published in 1922.

He joined The Institution as a Student in 1905 and was elected an Associate Member in 1911 and a Member in 1938. He was a member of the Transmission Section Committee 1937–38 and again 1943–46. C. T. W. S.

ARCHIBALD GEORGE McDONALD

Archibald George McDonald, O.B.E., T.D., B.SC.(ENG.), who died on the 11th July 1956 after an illness lasting several months, was born on the 11th June 1900.

He was educated at Bloomfield Central School and served an apprenticeship at Woolwich Arsenal from 1915 to 1919, during which time he studied part-time at Woolwich Polytechnic. He then entered a three-year full-time course at the City and Guilds Engineering College and graduated with a first-class honours B.Sc. degree in engineering. He spent two years subsequently with Mott, Hay and Anderson, consulting engineers of London, during which time he was directly concerned with the extension and reconstruction of the then City and South London Railway.

He entered the Post Office as a Probationary Assistant Engineer in July 1924, and was appointed to the Wireless Section, Dollis Hill, where he was concerned with the provision of auxiliary power equipment at Rugby Radio Station, with drawing up specifications, testing at works and installing on site the complete power equipment for the short-wave transmitters at Devizes, Portishead and Rugby radio stations, and with the provision of power equipment for Cairo and Leafield short-wave transmitters.

In 1933 he was transferred to Newcastle as Power Engineer, promoted to Sectional Engineer, Middlesbrough, in December 1934, and appointed Area Engineer in 1936. He came south to the London Engineering District as Executive Engineer in December 1937, and was promoted to Assistant Staff Engineer, Equipment Branch of the Chief's office, in August 1938.

He was keenly interested in the Territorial Association and was mobilized on the 2nd September 1939, and continued in military service until September 1945, rising by that time to the rank of colonel. In the course of his military career in the Royal Army Ordnance Corps and later in the Royal Electrical and Mechanical Engineers, he held the appointment of Deputy Director Mechanical Engineering, and in recognition of his distinguished war service he was made an O.B.E. in 1946; in addition he held the Territorial Decoration.

On demobilization, Col. McDonald returned to the Post Office as Chief Motor Transport Officer.

He joined The Institution as an Associate Member in 1936 and was elected a Member in 1944. He was also a Member of The Institution of Mechanical Engineers and an Associate Member of The Institution of Civil Engineers. L. H. H.

HAROLD EDWARD MIDGLEY

Harold Edward Midgley, M.A., who died on 1st July 1956, was born in Yorkshire on 7th February 1880. To the end of his life he displayed the sturdy qualities and the resilience of body and mind traditionally associated with the county of his birth. After being educated at Wakefield Grammar School and Queen's College, Cambridge, where he gained a B.A. degree in mathematics, he obtained practical experience in the municipal electrical department at York, followed by a year with Callender's Cable and Construction Co. He was then promoted to Chief Assistant of the Testing Department and remained with the company for two more years.

In 1905 he joined the electricity department of Erith Urban District Council as Mains Engineer, and was promoted within two years to Chief Assistant and Deputy Engineer. In 1909 his connection with steam-turbine manufacture started when he joined Fraser and Chalmers as Chief Assistant in the Turbine Department, where he remained for nine years. Although many other activities claimed his attention, steam turbines became the dominant interest of his life, and after successive positions with Dick, Kerr and Co., the English Electric Co., and the Foundation Co., he became Managing Director of Ruths Steam Storage, in 1928. Two years later he also became Vice-Chairman of Newton Bros. (Derby), a position he retained until his death.

Mr. Midgley's talents came to fruition in 1934 when he was appointed Chairman and Managing Director of the Brush Electrical Engineering Co., Loughborough. He joined this organization at a difficult time when the national policy of interconnecting power stations by the Grid system was just taking effect on the electricity supply industry, and the demand for small turbines had practically ceased. The Brush–Ljungstrom radial-flow steam turbine, then developed to 15 MW capacity, became his adopted child. With immense courage and enthusiasm he fostered the development of larger units of 20 MW and 30 MW, and by January 1937 a 37·5 MW set was put into service at Brighton. A similar set was commissioned in 1938.

These achievements enhanced his reputation as a turbine engineer and administrator, and he became widely known as an authority on radial-flow steam turbines.

A natural charm of manner coupled with a flair for friendship, and also conviviality when the occasion demanded, caused Mr. Midgley to make many friends in the industry, and not least among his friends were those who worked with him as colleagues or subordinates. He leaves a widow and two daughters.

His main relaxation was golf, which he played with characteristic proficiency and zeal almost to the end of his life. One of his keenest pleasures was to preside at the annual meeting of the Brush Golfing Society, and it delighted him to collect tribute from opponents who failed to match their skill with his on the links.

Mr. Midgley joined The Institution as a Member in 1920. He was also a Member of The Institutions of Civil and of Mechanical Engineers. J. H. R. N.

EDWARD ARTHUR RICHARDS

Edward Arthur Richards, M.B.E., B.SC.(ENG.), who died on the 20th June 1956, was born on the 8th May 1885. He was educated at Norwood Central High School, and received his practical training with Rawlings Brothers Ltd., Sharp and Co., and S. H. Lewin and Co., from 1900 to 1910, during the whole of which time he attended evening classes at the South-Western Polytechnic, Chelsea. He then became a full-time student at the City and Guilds Engineering College, where he gained a B.Sc.(Eng.) honours degree, and was awarded the Siemens Memorial Medal in 1913.

After a period as a lecturer in electrical engineering at the Borough Polytechnic, Mr. Richards joined the staff of Siemens Brothers and Co. in 1913; war service in the R.F.C. (later R.A.F.) followed between 1915 and 1919, when he

returned to the company and ultimately became head of the Telephone Equipment Division.

In 1929 he joined the European Commercial Department of the International Standard Electric Corporation, for which he carried out several foreign assignments in Antwerp, Paris and Malta. He was transferred in 1931 to Standard Telephones and Cables. Two years later he left this organization to take up the position of Chief Engineer with Broadcast Relay Services, but returned to Standard Telephones and Cables in 1936, and took charge of the sales, engineering and development groups of the Rectifier Division, pioneering in the United Kingdom the development of the selenium metal rectifier. He visited the United States during the Second World War in connection with the co-ordination of effort on the production of war materials. In 1946 he was made an M.B.E. for his work in increasing the production of selenium rectifiers during the war, and for initiating many improvements in their manufacture and application to meet the tremendous demands of the Services.

After the war he was selected by the Government to serve on committees investigating enemy wartime technical development.

After his retirement from Standard Telephones and Cables in 1954 he visited the United States as a consultant on rectifier production. He was an international figure in the field of metal-rectifier engineering, and wrote a book on the subject which was in course of publication at the time of his death.

Mr. Richards joined The Institution as a Student in 1909 and was elected an Associate Member in 1934 and a Member in 1942. He was awarded the Students' Premium in 1914 for his paper on 'Single-Phase Commutator Motors', and an Extra Premium in 1942 for his paper on 'Characteristics and Application of Selenium Rectifiers'. R. A. M.

JOHN SINNOTT

John Sinnott, O.B.E., who died on the 21st June 1956, was born on the 24th June 1867.

He joined the Post Office telegraph staff in Dublin in 1888, and, owing to his technical qualifications and examination successes, was transferred to the Engineering Department at Haverfordwest in 1891. During the succeeding ten years he obtained varied provincial experience, particularly in aerial trunk-line construction. In 1902 he was appointed to the design section of the Engineer-in-Chief's office, where he remained for six years, during which period he was largely responsible for the installation and maintenance by the Post Office of extensive fire-alarm systems for municipalities, notably those of Bristol and Manchester.

From 1907 to 1911 he served as Assistant Superintending Engineer in the London Metropolitan District, and he was then brought back to the Engineer-in-Chief's office in charge of the construction section dealing with all aspects of external line construction. In that section he introduced many important changes, including the adoption of the transposition system for aerial lines, the abandonment of the continuous twist, and the use of the well-known earthenware multiple-way self-aligning ducts in place of cast-iron pipes hitherto used for underground conduits.

During the 1914–18 War Mr. Sinnott was called upon to meet urgent requirements of the Army and Navy for line communication, and he was responsible for the design and manufacture of vast quantities of a large number of special cables. He also undertook research work for the detection of submarines, and was specially commended by the Director of the Anti-Submarine Department, Admiralty, and by Sir William Bragg. For these war services he was made an O.B.E. in 1921.

In 1922 came further recognition of his services when he was appointed Assistant to his friend of many years, Sir Thomas F. Purves, who was at that time Engineer-in-Chief. Together they carried out some early experiments on the use of radio as a medium of entertainment. Mr. Sinnott retired in 1928.

He joined The Institution as an Associate in 1893 and was elected a Member in 1911. P. J. R.

EDMUND BASIL WEDMORE

Edmund Basil Wedmore, C.B.E., first Director of the British Electrical and Allied Industries Research Association, who died on the 16th June 1956, was born on the 24th January 1876.

He received his technical and scientific education at University College, Bristol, and at Finsbury Technical College, London, being awarded the City and Guilds Silver Medal in 1896. He gained practical experience at the Bristol Corporation electricity works and as a demonstrator and lecturer at Finsbury Technical College under the leadership of that inspiring teacher Silvanus P. Thompson. Then followed twenty years of growing experience and responsibility as a Design Engineer (mainly of switchgear) with the British Thomson-Houston Co.

The year 1919 saw his appointment to the Electrical Research Committee, which had been set up in 1917 under the aegis of the British Electrical and Allied Manufacturers' Association and The Institution to foster means for minimizing shortages (due to submarine warfare) in certain materials essential to the electrical industry. Then came his appointment in October 1920 as Director and Secretary of the E.R.A., which had been established by the industry at the end of the previous month.

There, until his retirement at the end of 1944, Mr. Wedmore found ample scope for his great talents, and he was made a C.B.E. in 1938. Under his leadership an able and enthusiastic staff of scientists and engineers, together with over one hundred committees of experts, enabled the E.R.A. to make valuable contributions to many of the immediate and long-term needs of industry.

Mr. Wedmore was active in the field of international standardization and was a member of various committees of the International Electrotechnical Commission. He was present at the first meeting of the Conférence Internationale des Grands Réseaux Électriques, held in Paris in 1921, and was mainly responsible for the setting up of the liaison committee of that conference from which the present British National Committee sprang.

From his versatile mind came a large number of inventions. Most of these, of course, had connection with switchgear, which was his special subject, but others were concerned with such diverse matters as overload protection, colour photography, anti-wind teats for babies' bottles, and an inexpensive high-speed camera, which, designed in about 1926, is still in use.

Another facet of his mind was reflected in his interest in problems of multi-dimensional space, and many will remember the beauty of the many-sided or pointed cardboard models which he made to illustrate the appearance of four-dimensional objects as seen in perspective in three-dimensional space.

In his younger days he devised one of the earlier practical methods for the graphical analysis of waveforms. This

attracted considerable attention and was known as 'Wedmore's method'.

He retained his vigour of mind and body to the end; his freshness of mind was reflected in a remark which he made to a friend not long ago, 'The more I ask of life, the more I get from it'.

Mr. Wedmore, besides writing jointly one of the earlier books on electric switchgear,* made great contributions to knowledge in the field of electrical engineering, and his rare qualities enabled him successfully to pioneer the development of the E.R.A. through periods of storm and stress from tiny beginnings to a position of wide usefulness.

In later years, more especially after his retirement from the E.R.A., he became well known in bee-keeping circles for his many valuable contributions to knowledge.†

He had a modest and very human personality with a deep sense of loyalty to his colleagues. He was admired for his fairness in all matters, his rapid grasp of essentials and his courage in following a course of action once it had been decided on. He was generous and sympathetic to any in real trouble, although these inner characteristics were sometimes hidden by his matter-of-fact style.

He was twice married, first to Miss E. H. Brison and secondly to Miss W. A. M. Parry. There were a son and two daughters of the first marriage and a son and daughter of the second.

Mr. Wedmore joined The Institution as a Student in 1894 and was elected an Associate in 1897, an Associate Member in 1902 and a Member in 1912. He wrote many papers which were published in the *Journal*, being awarded the Students' Premium in 1896, the John Hopkinson Premium in 1914, the Institution Premium in 1918 and the Kelvin Premium (jointly with W. B. Whitney and C. E. R. Bruce) in 1929. He served as a Member of Council from 1941 to 1944. He was also a Fellow of The Institute of Physics. W. B. W.

* WEDMORE, E. B., and TRENCHAM, H.: 'Switchgear for Electric Power Control' (Oxford University Press, 1924).
† See the tribute to his work by C. G. BUTLER, *Nature*, 1956, **178**, p. 239.

CORRESPONDENCE

WHAT IS PERMEABILITY?

From I. L. STEFANI, B.SC., ASSOCIATE MEMBER

The writers of the letters published in your correspondence column on the subject of permeability have fallen back on arguments which have been used for more years than I can remember. There is simply a new setting. Advocates of the M.K.S. system have admittedly moved some inconvenient constants to places where technical calculations are made somewhat infrequently, and they have improved the mechanical units, but the real quarrel with them is centred around the terms 'permeability' and 'permittivity'.

There have always been two schools of thought on B/H and D/E, and it is not possible to reconcile them because the methods of developing electrical theory by the followers of the two schools differ in every respect. I am an electrical power engineer and not a physicist, but I am convinced that the simplest way of logically presenting the science is to make H the basic field vector and B the result of combining an external excitation with a local doublet distribution,* i.e. H equals B in vacuum. This starting point means that ampere-turns per unit length are not equivalent to H so that those who worry about dimensions can look for trouble here. It also means that μ_0 is not 1 or $4\pi \times 10^{-7}$; it just does not and indeed cannot exist. I appreciate the fact that many engineers (styled by some mathematical physicists as 'meddling technicians') are able to obtain their formulae more rapidly by defining B/H as other than a numerical ratio and surmounting some of the mental hurdles by recourse to experiment. I have no quarrel with these gentlemen. I am, however, very much concerned with those who insist that their peculiar mental gymnastics represent a sound philosophy, and thrust their unwelcome ideas on all and sundry in the guise of pure logic.

Having worked for a number of years on methods of presenting the classical theory to elementary classes of engineering students, I had just succeeded in 'filling in the gaps' in the textbooks of physics in a manner likely to be acceptable to the more 'down to earth' type of engineer, when the M.K.S. system set back my work for two years. Naturally I cannot pretend to like it and I am unable to find any logical sequence running through the various books and papers on the subject.

At a recent meeting of The Institution's Education Discussion Circle I spoke about this matter just after Professor Cullwick, and so I may have been partly responsible for his letter. In this letter I see a plea for a more liberal point of view which would enable the two schools of thought to co-exist after the manner of the 'good old C.G.S. days'. I agree completely with what he has written.

I add some answers to Professor Kapp, with μ defined in terms of a doublet analysis as a starting point; the numbers refer to his numbered sections:

(i) I cannot see why equation 1a is algebraically better than equation 1b any more than $x + y$ is better than $x + 2y$. Is it really practical to test the equation by experiment unless we postulate or fix the degree of polarization? In this event we should be measuring a defined constant.

(ii) There is no substance in the cavity.

(iii) No comment in view of the above.

(iv) Sir James Jeans in his 'Dynamical Theory of Gases' is forced to use the molecular kinetic energy and not the temperature when he is considering the distributions of velocity and energy. Temperature has no meaning when applied to the microscopic. Likewise B and H are essentially macroscopic quantities. (I am investigating alternatives to Kelvin's cavity definitions in terms of averages taken under different conditions.)

I should be glad to know if there are other engineers who believe, as I do, that analysis of the doublet field is one of the keystones of our basic science; I know there are many physicists who do.

* This does not imply that H is equal to the component of B due entirely to the primary excitation, which would generally be incorrect.

Mr. Stefani is a Lecturer at the Woolwich Polytechnic.

From G. BURNISTON BROWN, M.SC., PH.D.

As a physicist, I should like to support Professor Cullwick's vigorous defence of the classical K and μ; and his castigation of those who would give properties to nothing (free space). One of the most shameful incidents in the history of science was when the Committee of the Congrés International d'Électricité (Paris) in 1932 had to resort to a majority vote in order to decide that B and H were really different, and to introduce the bastard *oersted*. The feeling of shame was for me so great that I gave many months of thought to the problem, resulting in a paper entitled 'A New Treatment of Electric and Magnetic Induction' (*Proceedings of the Physical Society*, 1940, **52**, p. 577). This appeared during the war and has, no doubt, been overlooked, but Eddington, at any rate, thought that 'it cleared up the mysterious cavity business'. Authors who try to avoid cavity consideration in solids appear not to realize that cavities have a practical aspect: e.g. will a flat current-carrying coil produce the same effects if it is put in a disc-shaped slot as it will if closely surrounded and penetrated by the same medium (*ibid.*, p. 596)?

Hardly had I cast off sackcloth and ashes, when the rage for the M.K.S. system caused the subject to revive, including the objectionable features. Professor Carter's treatment, recommended by Professor Cullwick, does avoid the worst of these, but it is hard to say whether the whole subject has not been made more difficult from the physical viewpoint. Instead of K, we have λ, ϵ and ϵ_0; and instead of μ, we have another λ, μ, and μ_0. Again, instead of the force (which can be felt) between permanent magnets (which can be seen and felt), or that between permanent electrets, the student is asked to concentrate on *flux*, which is a mathematical abstraction.

Whenever K and μ, straightforward symbols for the effects of the physical process of polarization, and defined as ratios in accordance with their measurement, are abandoned and replaced by 'multipliers', obscurity is bound to arise about whether the multipliers are affected by the units chosen, the medium or both. For example, the first equation in Professor Carter's book 'The Electromagnetic Field in its Engineering Aspects' is

$$F = \frac{\lambda Q_1 Q_2}{r^2}$$

and 'the multiplier λ' is said to depend on the surrounding medium. The second equation, a few lines further on, is

$$F = (8{\cdot}988 \times 10^9)\frac{Q_1 Q_2}{r^2} \text{ newtons (in vacuo)}$$

and the next is the gravitational formula

$$F = (6{\cdot}67 \times 10^{-11})\frac{m_1 m_2}{r^2} \text{ newtons}$$

These three equations naturally appear to the student to be similar: λ is said to depend on the medium; the first number in parentheses depends on the units adopted but would alter if the medium altered; and the second number in parentheses depends on the units but would not alter if the medium were changed. I cannot help thinking this is rather confusing.

No doubt, to engineers, the most important aim of the instruction given is to produce people who can calculate results correctly and easily: to the physicist, the most important feature is physical insight and understanding, and it still seems to me that the treatment given by the great masters of physics, which exemplifies their own approach and insight, is the best for instructing physics students. I agree, therefore, with Professor Cullwick that we must keep the difference between the procedures of physicists and engineers as small as possible.

Dr. Brown is a Reader in Physics at University College, London.

RADIO RECEPTION IN INDIA

From K. L. RAO, M.A., ASSOCIATE MEMBER

I have read with interest the two papers entitled 'The Prediction of Maximum Usable Frequencies for Radio-communication over a Transequatorial Path' by G. McK. Allcock, and 'Asymmetry in the Performance of High-Frequency Radiotelegraph Circuits' by A. M. Humby and C. M. Minnis, which appeared in the *Proceedings*, July 1956, Part B. It is perhaps more convenient to consider these two papers together, since some of the problems are closely related. The path considered in the first paper, and those between London and Australia and between London and South Africa considered in the second paper, come into the transequatorial category.

Broadcast organizations like the B.B.C. can perhaps furnish valuable information on several of their circuits. Listeners' observations also may quite often be useful.

I have for several years been listening to the B.B.C. and the A.B.C., and to Tebrau and Radio Ceylon, which quite often relay the B.B.C. programmes. India, particularly the northern region, appears to be happily situated for the London–Melbourne circuit, being almost in the mid-region of the path. Simultaneous observations on the B.B.C. and A.B.C. transmissions would perhaps give valuable information on the circuit peculiarities such as those reported in these two papers.

I suppose there is a predominant mode of propagation for each circuit, and so long as the optimum frequency is used this mode does not vary from frequency to frequency. This would mean that the most probable angle of arrival for a given circuit is primarily guided by the predominant mode of propagation. The design of the aerial system for the oversea circuits appears to have been based on the multiple-hop theory, and the success of the various broadcast circuits apparently bears out this theory. The multiple-hop method may be a solution to the problem of prediction of maximum usable frequency within reasonable limits.

In this region the A.B.C. transmission directed to London seems to be better received than either the signals directed to India or those directed to Australia from London. This phenomenon occurs particularly during the peak listening hours here, i.e. between about 1900 and 2200 Indian Standard Time. On one occasion I remember that both the B.B.C. and A.B.C. transmissions came up on the same wavelength, 31 m, on their evening transmission (2130 I.S.T.), owing probably to some misunderstanding. The A.B.C. signals were by far the superior. This appears to contradict the inference drawn in the second paper that noise is carried from east to west from regions of maximum thunderstorm activity, which appears to be centred very near India. However, as the authors have pointed out in their concluding remarks, a final conclusion on the reasons of asymmetry in the radio circuits considered can be drawn only by simultaneous observations over several years. The broadcast organizations may perhaps lend valuable help over this.

Mr. Rao is with All India Radio.

MONOGRAPHS AND PAPERS
published individually this month

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MONOGRAPHS

The Effect of Magnetic Saturation on the D.C. Dynamic Braking Characteristics of A.C. Motors

MONOGRAPH No. 206 U

O. I. BUTLER, M.Sc.

It is shown that the effect of magnetic saturation on the d.c. dynamic braking characteristics of a.c. motors can be determined by a mathematical method of analysis which uses the net value of the equivalent alternating magnetizing current, rather than the fractional speed, as the independent variable of functions expressing the values of the secondary-circuit current and braking torque. The method is applicable to both asynchronous and synchronous polyphase machines, and to single-phase squirrel-cage motors. It is noted that the deep-bar type of squirrel-cage induction motor, in which the rotor resistance varies appreciably with the rotor speed, does not present any special difficulty in applying the method.

A quantitative relationship is derived for the maximum-torque conditions. The variation of the maximum torque, and of the critical-speed/secondary-resistance ratio, with the direct primary current is determined for values of the latter up to four times the rated primary current, and with zero, normal and excessive values of secondary reactance. It is shown that even when the existence of the normal reactance only is neglected, the maximum torque may be in error to the extent of 16%. Still greater errors arise from the neglect of magnetic saturation, even with the direct primary current limited to the rated value.

The Describing Function Analysis of a Non-Linear Servo Mechanism subjected to Stochastic Signals and Noise

MONOGRAPH No. 207 M

P. N. NIKIFORUK, B.Sc., Ph.D., and J. C. WEST, B.Sc., Ph.D.

A technique is presented for evaluating the response of a specific type of non-linear servo mechanism to random signals, to sinusoidal signals contaminated by noise and to random signals contaminated by noise. In particular the authors consider a second-order servo mechanism incorporating derivative-of-error stabilization and subjected to torque limitation. Theoretical responses are evaluated for a wide range of parameters, and experimental verification is included.

The analysis presented in the monograph is basically an extension of the describing function technique and can be applied to any second-order servo mechanism incorporating, either by design or inherently, a simple amplitude-dependent frequency-insensitive non-linearity.

The Change of Air-Gap Flux in Electrical Machines due to the Displacement of Opposed Slots

MONOGRAPH No. 208 M

G. LIEBMANN, D.Phil.

The change of air-gap flux in electrical machines due to the relative displacement of rows of opposed slots is measured, for a series of slot widths, with the aid of the resistance-network analogue. The results are presented in graphical form and can be scaled for different values of slot pitch.

Non-Linear Distortion in Transistor Amplifiers at Low Signal Levels and Low Frequencies

MONOGRAPH No. 209 R

N. I. MEYER, Ph.D., M.Sc.

An analysis is made with the purpose of establishing analytical methods of calculating the non-linear distortion of sinusoidal signals in the input and output circuits of transistor amplifiers at low frequencies and low distortion levels. The transistor is regarded as an 'almost linear' four-pole, and characterizing matrix equations and T-network equivalent circuits are developed, under the further assumption that the second harmonic is of greater magnitude than the higher harmonics. By using these equations or the equivalent circuits it is possible to calculate second-harmonic distortion of the signals by well-known methods from the linear theory; and it is indicated how the principle may be extended to allow calculation of the third-harmonic distortion, too. The principle is used to calculate the output distortion factor for some simple amplifiers, and it is shown that the input and output distortion of the common-emitter amplifier may cancel under special working conditions of the amplifier. From the analytical expressions developed it is possible to fix these conditions so that a considerable reduction of the second harmonic in the output signal is obtained. The expressions developed have been verified experimentally.

Intermodulation in Bridge Detector Amplifiers

MONOGRAPH No. 210 M

G. J. JOHNSON, B.Sc., and A. M. THOMPSON, B.Sc.

A discussion is given of the effects of intermodulation in bridge detector amplifiers and the means by which they may be minimized. A figure of merit is defined to assess the

performance of an amplifier, and is used to demonstrate the importance of tuning and feedback. The problems associated with the use of amplifiers containing both tuned and untuned stages are discussed, and the arrangement of these stages for minimum intermodulation is derived. The paper includes a description of a practical amplifier for use at 1 and 1·6kc/s in which the intermodulation is unusually low.

On the Amplification Factor of the Triode

MONOGRAPH No. 211 R

PROFESSOR E. B. MOULLIN, M.A., Sc.D.

This monograph discusses why a triode valve has the property that any assigned anode current is a function of the anode potential plus a constant times the grid potential. Unlike the classic methods of approach, the author's method is to find the values which these two voltages must have when an assigned anode current is flowing. He starts by reminding the reader that if a given current is crossing the barrier of a diode, the electrons in that stream propel themselves by means of their own mutual repulsions and are not assisted in their path by the attraction of the positive charge on the anode. The means by which the anode potential operates is through the positive charge which it causes to exist on the cathode, thereby regulating the proportion of the total cathode emission which crosses the barrier. Once this current is assigned, then the electrons in it continue to gather kinetic energy until they are brought suddenly to rest by colliding with an anode interposed in their path. The potential of this anode is determined from the kinetic energy they have attained.

If a negatively charged grid is interposed in the path of a given stream of current leaving a barrier, then it is shown that this negative charge produces scarcely any electric force in the region between the barrier and the plane of the grid. Once the electrons have passed through the meshes of the negative grid they will experience a strong repulsive force from it and will thereby be accelerated in their path. At any point in that path they will have attained additional kinetic energy equal to the work put into them by the negative charge on the grid: accordingly the velocity with which they strike the anode is known and thus the potential which that anode must have. By means of the particle dynamics of their flight, it is found that, for any assigned current, there is a linear relation between the anode voltage and the negative charge on the grid.

A proof is given that the amplification factor of a triode is independent of anode current, a fact well known by experiment, and such a proof is believed to be novel.

PAPERS

The Absolute Calibration of Voltage Transformers

PAPER No. 2213 M; PART A

W. K. CLOTHIER, B.Sc., M.E., and L. MEDINA, Dipl.Ing.

The paper will be published on the 24th November

An account is given of equipment and measuring techniques in use at the National Standards Laboratory, Australia, for calibrating voltage transformers. The equipment employs 3-terminal air-dielectric capacitors to form a voltage divider, the ratio and phase defect angle of which are determined by a self-contained technique. Owing to the use of virtually loss-free capacitors, the phase angle of the divider is negligibly small.

Two methods are described for calibrating transformers. In one, ratio balance is obtained by means of a small auxiliary variable-ratio voltage transformer, and phase balance by current injection into one of the detector bridge junctions. In the other method, ratio balance is provided by a variable 3-terminal air-capacitor in the low-voltage arm of the divider, and phase balance by voltage injection in series with that arm, a feedback amplifier providing a low-impedance injection circuit. In both methods the accuracy of measurement is approximately 2 parts in 10^5 in ratio and 0·05′ in phase angle.

The air-dielectric capacitors used in the voltage divider are tested to ensure that they have no significant voltage coefficient of capacitance or loss angle.

To be read on the 4th December 1956.

TECHNICAL PUBLICATIONS

E.R.A. REPORTS

Copies of the under-mentioned E.R.A. Reports can be obtained from the British Electrical and Allied Industries Research Association, Thorncroft Manor, Dorking Road, Leatherhead, Surrey. The price of each report is given, and, unless otherwise stated, the cost of postage on a report is 4d.

G/XT154 **Post-Arc Conductivity in Gas-Blast Circuit-Breakers** by A. M. Cassie and F. O. Mason. 12s. 6D.

The post-arc conductance observed in a gas-blast circuit-breaker is shown to depend on the gas flow, i.e. on the axial pressure gradient in which the arc column is situated. The time-constant or constants associated with the arc column are similarly related to the pressure gradient. The experiments cover a current range up to 18 kA r.m.s. at 7–10 kV r.m.s., and peak values of post-arc current of 23 A have been observed.

L/T325 **The Dielectric Properties of Silicone Rubbers** by E. Rushton and G. Russell. 7s. 6D.

Five grades of silicone rubber, containing oxides of silicon, titanium, zinc and iron as filler, have been examined over the frequency range 60 c/s to 24 000 Mc/s and the temperature range −70 to +200° C. All the silicone rubbers have higher dielectric losses than the high-viscosity silicone liquids on which they are based, and this difference is mainly caused by the fillers. The silicone rubber containing silicon-oxide filler is the one whose dielectric properties are least affected by changes of frequency and temperature, the highest value of loss tangent being 0·03. The other rubbers have values as high as 0·05 to 0·10.

L/T346 **Realizability, Kramers–Kronig Relations, and Fuoss–Kirkwood Dielectric** by H. Pelzer. 4s. 6D.

A recent statement by Brachman and Ross Macdonald that the commonly accepted conditions of realizability of a linear system are too stringent, and are not fulfilled for the Fuoss–Kirkwood dielectric, is shown to be incorrect. On the other hand, the usual formulation could be somewhat amplified when dealing with an admittance function which is analytically multi-valued. In this case only the principal value of the function has physical significance, and the 'lower sheets' of its Riemann surface are to be discarded.

SOME RECENT BOOKS

S. W. AMOS and D. C. BIRKINSHAW

TELEVISION ENGINEERING PRINCIPLES AND PRACTICE. Vol. II. Video-Frequency Amplification

ILIFFE. 270 PP. 35S.

For many years now the need has been felt for a comprehensive but concise treatment of video amplification problems and techniques of a standard suitable for young engineers. Volume II of 'Television Engineering' by Amos and Birkinshaw goes a long way towards this need. It is called a training manual, and has in fact all the necessary attributes of a training textbook. After a preliminary introduction to the problems of video-frequency amplification, with reference to phase and frequency response, the reader is taken by logical and well-illustrated steps through the metamorphosis of wide-band circuits, starting with simple resistance-capacitance circuits and graduating to several of the more widely used reactance-compensated amplifiers, distributed amplifiers and feedback amplifiers. A chapter on phase equalizers is included and treats the subject in a simple, straightforward manner that should have a wide appeal.

Throughout the book numerical examples are included to illustrate the theoretical approach, which for a training manual is laudably free from any other than simple mathematics. The subjects of maximally flat frequency response and group delay are introduced for several types of circuit with a simplicity of treatment that should be specially appreciated by the designer to whom the names of Bode, Nyquist, Laplace, Heaviside, etc., are a little frightening.

Likewise, in the chapter on feedback, the treatment is delightfully simple, while still adequate for the majority of everyday design problems. It would, perhaps, have been appropriate in Chapter 17 to sound a note of warning on a frequently overlooked characteristic of simple negative-feedback amplifiers, namely the decreasing amplitude linearity with increasing frequency, a property which will become increasingly important if N.T.S.C. colour television is adopted in this country.

It is a little surprising that no reference has been made to shunt-regulated amplifiers, which are being used widely and increasingly by designers in the United Kingdom, the United States and Europe. No doubt this omission will be rectified when Volume IV, dealing with circuit techniques, makes its appearance. To this extent the book is not the comprehensive survey claimed in the preface. For its size, however, the scope of the subject treatment is excellent, and without doubt this is a publication which can be recommended to circuit designers both as a training manual and as a book of reference.

G. W. A. DUMMER

VARIABLE RESISTORS AND POTENTIOMETERS

PITMAN. 184 PP. 30S.

Mr. Dummer's book covers the whole field of variable resistors used in electronic equipment. An excellent account is given of wire characteristics, precision wire-wound variable resistors, and the more elaborate special resistors such as the sine-cosine potentiometer, but it is disappointing to find that apart from the catalogue at the back of the book only half a dozen pages are devoted to the carbon-track variable resistor. The carbon resistor and the simple types of wire-wound resistor are the most widely used mass-produced types of variable resistor, and the variable carbon resistor is still a less satisfactory component than it should be. It presents many problems worthy of discussion. Contact or rotational noise in carbon-track volume controls is a recurrent trouble in radio and television equipment and the methods of measuring noise of this kind, with an analysis of some of its known causes, would have been of interest. The performance of carbon tracks under humid conditions and their resistance to wear would also bear examination. In the brief discussion of carbon controls it is said that 'a carbon (graphite) brush is generally used'. Only one of the major manufacturers is known by the reviewer to use such a brush.

This book contains some very useful tables of physical properties of resistance alloys, and a number of tables, formulae and nomograms covering the design data of wire-wound variable resistors. It is most unfortunate that in Table 1.2, covering climatic testing, the provisions of I.E.C. Publication No. 68 have been misquoted, with the result that the close parallel between the international specification and B.S. 2011 has been obscured. The relative-humidity and cold-temperature figures both need correction.

This is an interesting book containing much valuable information. It has some leaning towards an armed-service viewpoint, and more could have been said about the cheap but interesting components still widely used in the industry. Mr. Dummer has concentrated a little too much on the cake and almost forgotten the bread and butter. The book has a useful bibliography.

A. F. GIBSON (*General Editor*) and others

PROGRESS IN SEMICONDUCTORS, VOL. 1

HEYWOOD. 227 PP. £2 10S.

The phenomenal growth of interest, during the past decade, in the industrial applications of semi-conductors has resulted in a spate of publications, and papers on this subject are now appearing at the rate of about a thousand a year. There is therefore an obvious need for review articles to enable the non-specialist to keep abreast of the times, and the book under consideration is the first volume of a series devoted to this end. It is intended that future volumes shall appear annually.

The present volume contains seven articles and all of them are by recognized experts. The engineer whose interest lies chiefly in semi-conductor devices will be particularly interested in Dr. N. B. Hannay's account of recent work on silicon and in the review of high-frequency transistors by Dr. J. Evans. These will give him an excellent summary of the position as it was a year or so ago, but he should be warned that considerable progress has been made since the articles were written. In particular, there is no mention of the double-diffusion method of making high-frequency transistors, which appears to be extremely promising.

Dr. Hogarth has contributed an interesting summary of the uses of germanium filaments in semi-conductor research, which should be of great value to teachers who may wish to repeat some of the classic experiments on the measurement of mobilities, life times, and so forth, for purposes of instruction.

The remaining articles deal with various matters of importance in the theory of semi-conductors, but will probably be of more interest to the physicist than the engineer. Professor

Garlick's review of the electrical properties of phosphors is a timely reminder that silicon and germanium are not the only semi-conductors in existence.

Summing up, one may say that this book will be of value to anyone who wishes to keep up to date with progress in semi-conductors, and future volumes will be awaited with interest.

ARTHUR S. LOCKE and others

GUIDANCE

PRINCETON: VAN NOSTRAND. 746 PP. £4 10S.

This book is the work of many authors, who severally discuss the various branches of mathematics and science upon which the art of missile guidance depends.

Seven chapters deal mainly with newly available matter, but in a qualitative manner, discussing the general problem, prior developments in recent years, tactical considerations, pre-launching and launching, economic considerations, guidance systems, and the system concept. These chapters are easily read, and serve to give a good general survey of the field; Chapter 16, on guidance systems, is the most useful of them, and also contains the largest bibliography in this group; it describes generally many different missile guidance systems, and discusses quantitatively the radar equation. There is a section in Chapter 8 on the terminology of errors, which is somewhat uninspired.

The authors deal mathematically with the analysis of flight paths; bandwidth studies; and simulation, computation and telemetry. This is some of the most valuable material in the book. Chapter 12 considers five types of flight path: the beam rider, where the missile remains on a straight line from control point to target; the pure pursuit course; deviated pursuit course (using a fixed lead angle); constant bearing course; and proportional navigation, in which the rate of turn of the missile is proportional to the rate of turn of the sight line from missile to target. Equations of motion are set up, assuming non-manoeuvring targets, and trajectories are obtained from them for various parameters. Chapters 17 and 18 deal with a hypothetical, semi-active missile system using pursuit-course navigation. After discussing the range and servo requirements of the radar equipment, the authors turn to space geometry and kinematics. They consider the auto-pilot and then the behaviour of the whole missile under guidance. These are interesting chapters but there are one or two obscurities in the argument. Chapter 19 gives a useful general discussion of simulation and telemetry. The author describes the way in which problems are tackled by simulators, the complicating factors of the real problem being introduced to the simulator gradually. He comments on problems of simulation rather than telling the reader how to deal with simulation in detail, and the chapter is the more useful for that. There is a very interesting section on the simulation of a missile by means of a conventional aircraft.

The remainder of the book deals in the main with established branches of physics and mathematics of importance in missile guidance. Chapter 5 on emission, transmission and detection of the infra-red is an excellent summary of the subject, and with its extensive bibliography, is among the best chapters in the book. Chapter 6 on mathematical groundwork, and 7 on servo theory, contain a lot of useful theory, but the newcomer to the subject will find them too condensed for proper understanding. They contain a very useful discussion of stability in feedback systems. Chapter 14 considers the behaviour of the missile airframe as an element in the control loop. After a brief qualitative discussion the author derives the transfer function of a cruciform missile in pitch and roll, and discusses the steady-state response of the system as a function of frequency, considering in turn pitch angle, roll angle, flight path vector, and angle of attack. The effect of variation in parameters is discussed. This chapter will be of value to those who are not versed in aerodynamics, but who need some idea of how an airframe behaves in flight.

Chapter 3 deals with map projections, the effects of the earth's rotation, terrestrial magnetism, and navigation. The treatment is rather too brief and contains some misleading statements, particularly in connection with centrifugal force and gravity, and the Coriolis forces, which suggest an imperfect understanding of the factors involved. The chapter as a whole gives insufficient indication of what it leaves out, and it does not have enough references to other sources.

Chapter 4, on transmission of radio waves, is a useful summary of the subject. In considering dual-path transmission, however, the author ignores the 180° phase change which takes place in a horizontally polarized wave on reflection from the surface of the sea, and this may mislead the uninitiated, although the proper phase is given in Fig. 4-6*b*, which is reprinted from another work. The concluding section, on attenuation of radio transmission through flames, is good.

Chapter 9 deals with measurement of missile motion, and includes elementary notes on compasses and gyros. Accelerometers are treated in considerable detail from the point of view of their equations of motion, and the rate gyro receives some attention. Chapter 10, on detection and information gathering, starts with a simple description of methods of modulation. There follow a description of Loran from the point of view of its geometry, and a general description of pulsed and c.w. radar equipment, using simple block diagrams. The main elements of radar sets are then described, with sections on a.g.c. loops and range tracking loops, and the use of radar beacons.

To sum up, it seems that the value of the book lies in the newly available matter it contains, and that its main appeal will be to those who are newly entering the guided-missile field. The remainder of the book may be read with interest, but is hardly suitable for use as a reference- or text-book, and the inclusion of summaries of relevant established techniques may prove a disadvantage if they divert attention from more authoritative texts.

R. ROST

KRISTALLODEN TECHNIK

BERLIN: WILHELM ERNST AND SON. 450 PP. £2 5S. APPROX.

This book is a much enlarged second edition of a booklet published in 1954.

Section A is a concentrated review of the basic physics of germanium and silicon and of the forms and principles of operation of point-contact and junction devices.

In Section B are described the techniques employed in the preparation of high-purity monocrystalline germanium, in the measurement of electrical resistivity and minority-carrier lifetime, and in the fabrication of point-contact and junction diodes and transistors. The circuit properties of these devices and some methods of testing them are outlined.

Section C is a compendium of circuit applications, ranging from simple diode detector circuits to a theoretical analysis of the conditions of oscillation of a feedback oscillator.

Section D comprises a collection of manufacturers' data, in detail for German and in summary for American types, presented in a variety of ways depending on the manufacturer.

The 'hybrid' system of parameters is employed in several of the presentations although no mention of it is made elsewhere in the book.

There is still an unfortunate lack of agreement (and some lack of clear thought) among writers on transistors as to the proper letter symbols for the various physical and electrical parameters. In this book some important symbols are used with different meanings on different pages. Thus α is defined in the physicist's language on p. 53 as the product $\gamma_e\beta\gamma_c$, the three factors being clearly defined in their accepted senses (though α* is more usual than γ_c for collector-current gain), while on p. 150 α is defined as R_{21}/R_{22}, where the R's are in turn correctly defined as 4-terminal network parameters. These two alphas are not the same, since the first implicitly assumes zero base resistance, whereas the second is more general and should preferably be known by a separate symbol. On p. 152 β is defined as R_{21}/R_{11} (the open-circuit voltage amplification factor of the real transistor), which is not related in any simple way to the base transmission factor β. On p. 154 γ is defined as the optimum power gain.

The discussion of equivalent circuits is limited to the simple low-frequency T-circuit with a series voltage-generator of e.m.f. equal to $r_m i_e$, but, if the alternative current-generator had been considered, the most appropriate representation of the current generated would be by the physicist's α multiplied by i_e—as is already used by some writers. The discussion of the frequency dependence of any parameters is limited to one or two passing references to that of 'alpha' (not always defined) and to almost casual mention of the collector capacitance C_c at a very late stage of the section on 'applications'.

The publication of supplementary sections is promised, initially as separate booklets,* to cover developments in the subject, and it is to be hoped that it will be possible to clarify the points noted above in the not too distant future. The present volume is well printed and illustrated.

* The first of these has recently been published.

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BOOKS

FLÜGGE, S. (Editor) 53

Handbuch der Physik. Band XIX Elektrische Leitungsphanömene 1. (Encyclopedia of Physics. Vol. 19. Electrical conductivity 1.)

Berlin, Springer-Verlag, 1956. pp. vi, 411. 25 × 17 cm. £5 11s. 8d.

The second volume of this work to be added to the Library. It is in English and deals with the electronic structure of solids, electric and thermal conductivity in metals, and photoconductivity.

GIBSON, A. F., and others (Editors) 621.315.59

Progress in Semiconductors.* Vol. 1

London, Heywood, 1956. pp. vii, 220. 25 × 16 cm. £2 10s.

The first of a series of annual volumes containing articles by specialists which review progress in semi-conductors. The articles will range from the purely chemical to applications such as transistors, and will cover all important aspects of the subject. This volume includes contributions on recent advances in silicon, germanium filaments, the design of transistors to operate at high frequencies, the photo-magneto-electric effects in semi-conductors. This book is reviewed on p. 698.

JACKSON, L. C. 536.48

Low Temperature Physics

4th ed. London, Methuen, 1955. pp. viii, 158. 17 × 11 cm. 10s. 6d.

A concise statement of the present position in low-temperature physics covering the production and measurement of low temperatures, liquid and solid helium, specific heats, and electrical conductivity and magnetism at low temperatures.

JONES, G. O. 666

Glass*

London, Methuen, 1956. pp. vi, 119. 17 × 11 cm. 8s. 6d.

In the past glass technology has grown up largely as an empirical study. This monograph is a scientific study of the properties of glass. It contains, nevertheless, a surprising amount of practical information for a book of its size, to which reference is facilitated by an adequate index. There is also a bibliography of books and articles on the scientific aspect of glass published since the war.

KAYE, G. W. C., and LABY, T. H. 53(083)

Tables of Physical and Chemical Constants and Some Mathematical Functions

11th ed. London, Longmans, Green, 1956. pp. vi, 233. 26 × 17 cm. 25s.

Since the 10th edition appeared in 1948 this work, including the individual tables in it, has been completely revised under the direction of an editorial panel of four. Although the original authors are both dead the general style of the original work has been retained.

MACMILLAN, R. H. 658.2

Automation. Friend or Foe?*

Cambridge, University Press, 1956. pp. viii, 100. 19 × 13 cm. 8s. 6d.

Beginning with a brief history of the development of automation, this short book goes on to discuss the growing social and economic problems it presents and their possible solution in the world to-day.

MARCUS, A., and GENDLER, S. E. 621.397.62

Elements of Television Servicing for Bench and Field

New York, Prentice-Hall, 1955. pp. xix, 587. 22 × 15 cm. £2 19s.

A book for television servicemen. It refers to American receivers and contains a detailed discussion of two television colour receivers. This book is a comprehensive treatment of the subject from a practical point of view in which only a necessary minimum of theory is introduced.

PLECHL, O. 621.316.3

Elektromechanische Schaltungen und Schaltgeräte. (Electro-mechanical switching circuits and apparatus)

Vienna, Springer-Verlag, 1956. pp. 224. 23 × 16 cm. £2 1s. approx.

A concise introduction to the theories of electromechanical switching circuits illustrated by descriptions of practical applications in power and telecommunication circuits.

RICH, S. F. 347.7

Municipal Law for the Engineer*

London, Macdonald and Evans, 1956. pp. xii, 223. 22 × 14 cm. 25s.

This work will mainly interest the county or municipal engineer. After describing the functioning of local government, it considers the law relating to sewerage and drainage; rivers and water supply; highways, streets and bridges; sanitation and refuse disposal; building control; town and country planning; and commons, open spaces and national parks.

SCHAUMJAN, G. A. 658.2

Automaten. (Automation)

2nd ed. Berlin, VEB Verlag Technik, 1956. pp. 610. 24 × 18 cm. £7 4s. approx.

An exhaustive treatment of the theory and practice involved in the production and operation of automatic machines and automatic production lines. The general problems of machine manufacture are discussed and new ideas described. Subjects considered include the capacity of the machines, choice of manufacturing processes, construction and efficiency. Particular attention is given to machines produced in the Soviet Union.

SKROTZKI, B. G. A. (Editor) 621.311

Electric Generation. Hydro, Diesel, and gas-turbine stations*

New York and London, McGraw-Hill, 1956. pp. ix, 458. 24 × 16 cm. £3 4s.

This is a detailed descriptive account, written for the non-engineering reader. It deals with the civil engineering and electrical side of hydro-electric stations. It describes also internal-combustion engines and gas-turbine prime movers used for driving electric generators, and their operation and control. This book will be reviewed in a future issue.

STEWART, B. 93 : 06

The Library and the Picture Collection of the Port of London Authority

London, Richards Press, 1955. pp. xxii, 86. 25 × 16 cm.

This interesting survey of the valuable works in the care of the Port of London Authority is divided into two parts; the first describes the wealth of the library and its functions; the second, the paintings and engravings, many of which are reproduced.

WAGNER, B. 621.395.645

Elektronische Verstärker. (Electronic amplifiers)

Berlin, VEB Verlag Technik, 1955. pp. 176. 21 × 15 cm. 39s. approx.

Designed principally for production engineers and technicians, after giving a description of the design and characteristics of electronic amplifiers, this book goes on to discuss the individual electronic components, such as vacuum tubes, thyratrons, ignitrons and mercury-vapour rectifiers. Description of the circuit design of the amplifiers receives the most attention.

WALKER, A. J. (Editor) 621.395.645

Public Address and Sound Distribution Handbook. A practical guide to the planning, installation and maintenance of electronic sound amplification equipment*

London, Newnes, 1956. pp. vii, 160. 22 × 14 cm. 21s.

WILKES, M. V. 518.5

Automatic Digital Computers*

London, Methuen, 1956. pp. x, 305. 22 × 14 cm. £2 2s.

Provides a general introduction to the principles underlying the design and use of digital computers. It discusses 'logical design' and 'programming' and will be useful to engineers concerned with the design of digital computers and mathematicians concerned with the use of them. This book will be reviewed in a future issue.

OTHER PUBLICATIONS

AGRICULTURAL AND MECHANICAL COLLEGE OF TEXAS ELECTRICAL ENGINEERING DEPARTMENT

Ninth Annual Conference for Protective Relay Engineers

Texas, 1956. pp. 140. 29 × 23 cm.

ASSOCIATION OF SUPERVISING ELECTRICAL ENGINEERS

A Cross Reference Index Between the 12th and 13th Editions of the I.E.E. Regulations for the Electrical Equipment of Buildings

London, A.S.E.E., 1956. pp. 22. 18 × 12 cm. Free, postage 2½d.

MINISTRY OF HEALTH

Report of a Working Party on Anaesthetic Explosions including Safety Code for Equipment and Installations

London, H.M.S.O., 1956. pp. 39. 24 × 15 cm. 2s. 6d.

NATIONAL ACADEMY OF SCIENCES—NATIONAL RESEARCH COUNCIL

Annual Report of the Conference on Electrical Insulation

Washington, National Academy of Sciences—National Research Council, 1956. pp. xi, 59. 27 × 21 cm. 24s. approx.

NATIONAL PHYSICAL LABORATORY

Standard Capacitors and their Accuracy in Practice. Notes on Applied Science No. 13

London, H.M.S.O., 1955. pp. iv, 10. 24 × 15 cm. 1s. 3d.

NATIONAL PHYSICAL LABORATORY

Wage Accounting by Electronic Computer

London, H.M.S.O., 1956. pp. 57. 24 × 15 cm. 2s. 6d.

ORGANISATION FOR EUROPEAN ECONOMIC CO-OPERATION

Europe's Growing Needs of Energy. How Can They Be Met?

Paris, O.E.E.C., 1956. pp. 120. 24 × 15 cm. 8s.

RADIO-ELECTRONICS-TELEVISION MANUFACTURERS ASSOCIATION and INSTITUTE OF RADIO ENGINEERS

Proceedings of the Symposium on Printed Circuits. Pennsylvania 1955

New York, Engineering Publishers, 1955. pp. 122. 28 × 22 cm. £2

RENTON, R. N.

Telex Service

London, Institution of Post Office Electrical Engineers, 1954. pp. 24. 28 × 22 cm. 2s. 6d.

SOCIETY OF BRITISH AIRCRAFT CONSTRUCTORS

Recommended Mechanical Standards for Electrical Accessories

London, S.B.A.C., 1956. 34 × 23 cm.

TELEVISION SOCIETY

Printed Circuits: a Bibliography issued by the Television Society

[London], Television Society, 1956. 25 × 30 cm.

UNITED NATIONS

Proceedings of the International Conference on the Peaceful Uses of Atomic Energy. Held in Geneva, 8th August to 20th August 1955. Volumes 1–16

New York, United Nations, 1956. 28 × 22 cm. £39

Forthcoming Events at Savoy Place

All meetings are held at Savoy Place, beginning at 5.30 p.m. (tea at 5 p.m.), except where otherwise stated. The nature of the meeting is indicated by the following key:

E EDUCATION DISCUSSION CIRCLE
I INFORMAL
M MEASUREMENT AND CONTROL SECTION
O ORDINARY
R RADIO AND TELECOMMUNICATION SECTION
S SUPPLY SECTION
U UTILIZATION SECTION

After each paper that has now been published is added the month that a synopsis appeared in the *Journal* under 'Monographs and Papers published individually this month'.

November 1956

M **20** *Tuesday* M. V. WILKES, M.A., PH.D., F.R.S., will open a discussion on 'Data Processing Equipment for Experimental Work; A Review of Techniques and Methods'†

S **21** *Wednesday* G. F. PEIRSON will open a discussion on 'Aluminium Conductor Cables'*

E **22** *Thursday* P. GODFREY, B.SC.(ENG.), will open a discussion on 'The Presentation and Demonstration of the Theory of Semi-conductors to Students of Electrical Engineering'* (At 6 p.m., tea at 5.30 p.m.)

S **28** *Wednesday* C. ADAMSON, M.SC.(ENG.), L. BARNES, M.SC.TECH., *and* B. D. NELLIST, M.SC.TECH. 'The Automatic Solution of Power-System Swing-Curve Equations' (Paper No. 2035 S)‖ *Synopsis:* May 1956

A. S. ALDRED, M.SC., *and* P. A. DOYLE, B.E. 'Electronic-Analogue-Computer Study of Synchronous-Machine Transient Stability' (Paper No. 2015 S)‖ *Synopsis:* June 1956

S. KANEFF, B.E. 'Dynamic Operation of an A.C. Network Analyser' [*Proceedings I.E.E.*, Paper No. 1947, October 1955 (**102**, Part A, p. 597)] (The paper will be read by I. MCDONALD)

O **29** *Thursday* PROFESSOR R. O. KAPP, B.SC.(ENG.). 'Differences of Opinion about Dimensions' (Paper No. 2167)‖ *Synopsis:* September 1956

December

RM **3** *Monday* Informal Evening on 'Electronics and Automation—The Use of Nucleonic Devices', at which there will be a talk given by DENIS TAYLOR, M.SC., PH.D.†

M **4** *Tuesday* W. K. CLOTHIER, B.SC., M.E., *and* L. MEDINA, DIPL.ING. 'The Absolute Calibration of Voltage Transformers' (Paper No. 2213 M)§ *Synopsis:* See page 697 (The paper will be read by G. W. BOWDLER, M.SC.)

O **6** *Thursday* G. F. TAGG, B.SC., PH.D. 'The Measurement of Earth-Loop Resistance' (Paper No. 2165 M)‖ *Synopsis:* September 1956

I **10** *Monday* G. L. E. METZ will open a discussion on 'Unsolved Problems arising from Automation'*

R **12** *Wednesday* E. W. HAYES *and* H. PAGE, M.SC. 'The B.B.C. Sound Broadcasting Service on Very High Frequencies' (Paper No. 2258 R)§

A. C. BECK, B.SC.(ENG.), F. T. NORBURY *and* J. L. STORR-BEST, B.SC.(ENG.) 'Frequency-Modulated V.H.F. Transmitter Technique with particular reference to the B.B.C. United Kingdom Service' (Paper No. 2267 R)§

U **13** *Thursday* FORBES JACKSON will open a discussion on 'The Thirteenth Edition of the Wiring Regulations'*

E **14** *Friday* P. GODFREY, B.SC.(ENG.), will open a discussion on 'The Teaching of Fundamentals of Transistor Circuits to Students of Electrical Engineering' before the Education Discussion Circle* (At 6 p.m., tea at 5.30 p.m.)

M **18** *Tuesday* C. G. GARTON *and* J. H. MASON, B.SC., will open a discussion on 'Breakdown in Dielectrics'†

S **19** *Wednesday* A. MORRIS THOMAS, B.SC., *and* D. F. OAKESHOTT, B.SC. 'Choice of Insulation and Surge Protection of Overhead Transmission Lines of 33 kV and Above' (Paper No. 2158 S)§ *Synopsis:* August 1956

* No advance information will be available and no Press report will be permitted.
† An abstract of the introduction will be available in advance.
‖ This paper has now been published individually.
§ This paper will be published not later than 10 days before the date of reading.

District Meetings

MAIDSTONE (At the Maidstone Technical College, at 6.30 for 7 p.m.)

1956

December 3 *Monday* L. GOSLAND, B.SC. 'Age and the Incidence of Fires in Electrical Installations' [*Proceedings I.E.E.*, Paper No. 1938 U, January 1956 (**103**, Part A, p. 271)]

HATFIELD (At the Technical College at 7 p.m. Tea at 6 p.m.)

December 11 *Tuesday* M. J. KELLY, PH.D., D.ENG., D.SC., LL.D., SIR GORDON RADLEY, K.B.E., C.B.E., PH.D.(ENG.), G. W. GILMAN, M.S., and R. J. HALSEY, B.SC.(ENG.). 'A Transatlantic Telephone Cable' [*Proceedings I.E.E.*, Paper No. 1741, September 1954 (**102**, Part B, p. 117)]

British Nuclear Energy Conference: Forthcoming Programme

NOVEMBER 22 *Thursday and* **23** *Friday*

A Symposium of papers on the Calder Works Nuclear Power Plant, which will be held at the **Central Hall,** Storeys Gate, Westminster, S.W.1. For details of the programme, see the September issue, p. 560, and the October issue, p. 625. All those wishing to attend are requested to obtain an application form from the Secretary, British Nuclear Energy Conference, 1–7 Great George Street, London, S.W.1.

The next meeting of the British Nuclear Energy Conference will be one sponsored by The Institution of Chemical Engineers, to be held on the 21st February 1957.

ANNOUNCEMENTS TO MEMBERS

THE HOMES FUND

SUMMARY OF CONTRIBUTIONS RECEIVED TO 25TH OCTOBER 1956

	No. of Contributors	£	s.	d.
£1 000 and over	6	6 000	0	0
£100 to <£1 000	30	6 586	3	0
£5 to <£100	811	8 641	6	3
£2 to <£5	1 940	5 299	0	8
Under £2	19 930	10 442	9	5
		£36 968	19	4

A CHRISTMAS LECTURE FOR OLDER SCHOOLCHILDREN

At the invitation of the Council, Mr. J. F. Coales, O.B.E., M.A., MEMBER, will deliver a Christmas Lecture on 'The Evolution of Automation'. The lecture, which is intended for older schoolchildren, will be given in the Lecture Theatre of The Institution on the 1st January 1957 at 3 p.m. and will be repeated at the same time the following afternoon.

Schools in the Home Counties are being invited to apply for tickets, and a number of tickets will be reserved for members' children, for which application should be made by the 1st December, stating for which afternoon they are required. As accommodation is limited, members are asked not to accompany their children.

The following is a synopsis of the lecture:

The replacement of physical labour by machines has been going on continuously throughout the centuries; first by the use of gravity, water and wind power; later by the use of solid fuels; and now by the use of nuclear power. Development of the use of natural sources of energy has been so successful that animal energy now costs 30 times as much as electrical energy, and human energy 480 times as much. There is, therefore, an enormous incentive to replace human labour by natural energy wherever possible and it is this which has resulted in the rapid advances of the last few years.

Water power was first used, in 350 B.C., for operating trip hammers in the grinding of cereals in pestles and mortars, and the water-wheel is known to have existed in the 1st century B.C., in China, Persia and the West. By the end of the 18th century, water-mills and windmills—there were many thousands in Britain—incorporated automatic controls so that they could be completely operated and controlled by one man. He could leave the mill to run untended while he dressed the stones not in use, tested the quality of the mill, or hoisted sacks to fill automatic hoppers, in just the same way as maintenance, quality control and transport have to be carried out in the automatic factory to-day. The 18th century also saw the introduction of automatic machines in the textile industry, and in the early 19th century Jacquard combined a punched-card automatic memory with an automatic weaving machine to make the Jacquard loom, which is still in common use. The 19th century also saw the development of calculating machines, which have in due course led to the computing engines and the automatic office which we know to-day.

Automatic production methods in the process and metal industries have developed rapidly during the past 25 years, largely owing to the application of automatic control techniques, although the principles are no different from that of the centrifugal governor invented by Thomas Mead for use in windmills and applied to the steam engine by James Watt in the 18th century. The underlying principles of automatic control will be discussed and demonstrated by a simple electrical control system. The successful application of automatic controls in industry in recent years has been greatly helped by the use of electronics, which has also made the automatic office feasible. The combination of automatic transfer lines and the automatic office, together with automatic methods of assembly and of inspection, makes the completely automatic factory a project that is feasible technically, if not yet economically. The possible organization of such a factory will be discussed to illustrate how the principles of automatic control must be used.

APPOINTMENTS AND NOMINATIONS

BRITISH STANDARDS INSTITUTION TECHNICAL SUB-COMMITTEES

Sub-Committee on Electric Shaver Supply Units (ELE/38/13)

The Council have nominated Mr. H. W. Swann, O.B.E., MEMBER, to serve as their representative on the above Committee.

Sub-Committee on Glossary of Terms used in Nuclear Science (USM/1/8)

The Council have nominated Mr. Denis Taylor, M.SC., PH.D., MEMBER, to serve as their representative on the above Committee.

CORNISH ENGINES PRESERVATION SOCIETY

The Council have nominated Sir Archibald Gill, B.SC.(ENG.), PAST-PRESIDENT, to act as a Trustee of the Endowment Fund of this Society and to serve as their representative on the governing body of the Society in place of Col. Sir A. Stanley Angwin, K.B.E., D.S.O., M.C., T.D., D.SC.(ENG.), PAST-PRESIDENT.

COMMITTEE ON RADIO INTERFERENCE

The Council have appointed Mr. O. W. Humphreys, B.SC., MEMBER, to serve as Chairman of the above Committee in place of Col. Sir A. Stanley Angwin, K.B.E., D.S.O., M.C., T.D., D.SC.(ENG.), PAST-PRESIDENT.

On the nomination of the Independent Television Authority, the Council have appointed Mr. P. A. T. Bevan, B.SC., MEMBER, to serve on the above Committee.

On the nomination of the Electrical Contractors' Association of Scotland, the Council have appointed Mr. J. Robb to serve on the above Committee in place of Mr. J. Morris Plucknett.

On the nomination of the Ministry of Fuel and Power, the Council have appointed Mr. A. T. Baldock, ASSOCIATE MEMBER, to serve on the above Committee in place of Mr. H. W. Grimmitt, MEMBER.

COMMITTEE ON RADIO EQUIPMENT FOR CIVIL AIRCRAFT

The Council have appointed Sir Archibald J. Gill, B.SC.(ENG.), PAST-PRESIDENT, who is Deputy Chairman of the above Committee, to succeed Col. Sir A. Stanley Angwin, K.B.E., D.S.O., M.C., T.D., D.SC.(ENG.), PAST-PRESIDENT, as Chairman.

WIRING REGULATIONS COMMITTEE

On the nomination of the Electrical Contractors' Association of Scotland, the Council have appointed Mr. D. G. Lindsay, ASSOCIATE MEMBER, to serve on the above Committee in place of Mr. W. Allan Smith.

The Council have appointed Mr. F. H. Mann, MEMBER, to serve on the above Committee in a personal capacity.

On the nomination of the Ministry of Fuel and Power, the Council have appointed Mr. A. H. F. Linton, ASSOCIATE MEMBER, to serve on the above Committee.

On the nomination of the Association of Consulting Engineers, the Council have appointed Mr. R. W. H. Couzens, M.A., MEMBER, to serve on the above Committee in place of Lt.-Col. K. H. Tuson, R.E., MEMBER.

COMMITTEE ON REGULATIONS FOR THE ELECTRICAL EQUIPMENT OF SHIPS

On the nomination of the Telecommunication Engineering and Manufacturing Association, the Council have appointed Mr. F. H. Fletcher, B.ENG., ASSOCIATE MEMBER, to serve on the above Committee in place of Mr. A. W. Montgomery, O.B.E., B.SC.TECH., MEMBER.

COMMITTEE ON REGULATIONS FOR THE ELECTRICAL EQUIPMENT OF AIRCRAFT

On the nomination of the Ministry of Supply, the Council have appointed Mr. J. F. Lewis, B.SC.(ENG.), MEMBER, to serve on the above Committee in place of Mr. S. F. Follett, B.SC.(ENG.), MEMBER.

COMMITTEE ON MODEL FORMS OF GENERAL CONDITIONS OF CONTRACT (ELECTRICAL)

On the nomination of the Association of Consulting Engineers, the Council have appointed Mr. F. H. Dickinson, M.ENG., MEMBER, to serve on the above Committee in place of Mr. J. F. St. G. Shaw, B.SC.(ENG.), M.I.MECH.E., MEMBER.

The Council have appointed Mr. J. F. St. G. Shaw, B.SC.(ENG.), M.I.MECH.E., MEMBER, to serve on the above Committee in a personal capacity.

COMMITTEE ON APPLICATION OF ELECTRICITY TO INDUSTRIAL PROCESS HEATING

The Council have appointed Mr. H. I. Hulme, ASSOCIATE, to serve as representative of the South of Scotland Electricity Board on the above Committee.

CODE OF PRACTICE COMMITTEE FOR MECHANICAL ENGINEERING

Code Drafting Committee on Oil Firing Installations and Conversions (MECP/6)

The Council have nominated Mr. C. H. Bottrell, ASSOCIATE MEMBER, to serve as their representative on the above Committee.

NATIONAL INSPECTION COUNCIL FOR ELECTRICAL INSTALLATION CONTRACTING

The Council have appointed Mr. S. E. Goodall, M.SC.(ENG.), VICE-PRESIDENT, and Mr. S. J. Emerson, M.ENG., MEMBER, to act as alternates for Mr. P. V. Hunter, C.B.E., PAST-PRESIDENT, and Mr. Forbes Jackson, MEMBER, respectively, who are the Council's representatives on the Board.

SOUTHEND-ON-SEA MUNICIPAL COLLEGE ENGINEERING ADVISORY COMMITTEE

The Council have nominated Mr. H. T. Prior, B.SC.(ENG.), ASSOCIATE MEMBER, to serve as their representative on the above Committee.

CITY AND GUILDS OF LONDON INSTITUTE ADVISORY COMMITTEE ON INSTRUMENT MAINTENANCE

The Council have nominated Mr. F. O. Morrell, B.SC., MEMBER, to serve as their representative on the above Committee.

YORKSHIRE COUNCIL FOR FURTHER EDUCATION

The Council have nominated Mr. A. J. Coveney, MEMBER, to serve as their representative on the above Council.

WIDNES COLLEGE OF FURTHER EDUCATION ENGINEERING ADVISORY COMMITTEE

The Council have nominated Mr. T. E. Houghton, M.ENG., MEMBER, to serve as their representative on the above Committee in place of the late Mr. K. R. Evans, O.B.E., M.A., MEMBER.

LEICESTER COLLEGE OF TECHNOLOGY ENGINEERING TRADES ADVISORY COMMITTEE

The Council have nominated Mr. L. Rushforth, M.B.E., B.SC., MEMBER, to serve as their representative on the above Committee.

COUNTY BOROUGH OF IPSWICH EDUCATION COMMITTEE

Council for Engineering

The Council have nominated Mr. C. T. Melling, C.B.E., M.SC.TECH., MEMBER, to serve as their representative on the above Council.

JOINT COMMITTEE ON PRACTICAL TRAINING IN THE ELECTRICAL ENGINEERING INDUSTRY

The Council have nominated Mr. G. N. Green, MEMBER, Mr. J. D. Stephenson, M.SC., PH.D., MEMBER, and Mr. R. F. Marshall, B.SC.(ENG.), to serve as their representatives on the above Committee in place of the late Mr. G. F. Peirson, MEMBER, the late Mr. Stanley Whitehead, M.A., D.SC., F.INST.P., MEMBER, and the late Mr. K. R. Evans, O.B.E., M.A., MEMBER, respectively.

KINGSTON TECHNICAL COLLEGE ADVISORY COMMITTEE FOR ELECTRICAL ENGINEERING

The Council have nominated Mr. J. W. T. Walsh, O.B.E., D.SC., M.A., MEMBER, to serve as their representative on the above Committee.

ELECTRICAL ENGINEERING ADVISORY COMMITTEE FOR EDUCATIONAL INSTITUTIONS IN NOTTINGHAM

The Council have nominated Mr. A. Brookes, M.ENG., MEMBER, to serve as their representative on the above Committee.

THE 1957 SUMMER MEETING

The Council, on behalf of The Institution, have accepted with pleasure an invitation from the Chairman and Committee of the North-Western Centre to hold the Summer Meeting next year in the area of the Centre. The Meeting will take place from Monday evening, 1st July, to Friday evening, 5th July. This advance notice is given to enable those interested to reserve the dates. Further details will be announced later.

CORRESPONDENCE

In view of the heavy volume of correspondence received daily at the offices of The Institution it is of the greatest assistance when members, in replying to letters received from the Secretary, quote The Institution's reference number. This saves the time of the routing staff and ensures that a letter not

only reaches the department concerned without delay but can be immediately linked with the previous correspondence. It is also helpful when members state their class of membership.

POST-ADVANCED LECTURES AT MANCHESTER

Some part-time lectures on mechanical and electrical engineering are being held at the Royal Technical College, Salford, and the Manchester College of Science and Technology. They are intended for students who have reached a standard at least equivalent to that of the Higher National Certificate. The courses, which are supported by the North-Western Centre of The Institution, begin in January or March 1957, and, since it may be necessary to limit the numbers, priority will be given to those who have notified the college concerned at least fourteen days before the start of the course. Most of the lectures will be held in the evenings. Among the subjects of interest to electrical engineers that the lectures cover are isotopes in industry, magnetic amplifiers, particle accelerators, sound recording, patents, and automatic welding. Further details may be obtained from the Honorary Secretary, Manchester and District Advisory Council for Further Education, Education Offices, Deansgate, Manchester 3.

'WIRING REGULATIONS—RECENT INTERPRETATIONS'

In view of the interest in the recent interpretation of the Wiring Regulations published in the October *Journal*, p. 598, separate reprints have been made available and copies may be obtained from the Secretary, price 1s. 3d. each.

THE ELECTRICAL ASSOCIATION FOR WOMEN

Miss Mary George, M.B.E., B.A., formerly Principal Information Officer of the Ministry of Agriculture, Fisheries and Food, has been appointed Director and Secretary of The Electrical Association for Women. Miss George succeeds Dame Caroline Haslett, D.B.E., J.P., COMPANION I.E.E., who retains her connection with the Association as Honorary Adviser.

CONSERVATION OF NATURAL RESOURCES

The Council of The Institution of Civil Engineers have arranged, during the first half of this session, six lectures to emphasize the importance of conserving the world's natural resources. The lectures are being delivered at 5.30 p.m. (tea 5 p.m.); The Institution of Civil Engineers, Great George Street, S.W.1, and members of our Institution will be welcome; but they should apply in advance to Great George Street for a ticket of admission. Particulars of the last two lectures are as follows:

29th November 1956	'Metallic Corrosion and Conservation' by W. H. J. VERNON, O.B.E., B.SC., PH.D., D.SC.
13th December 1956	'Use of Waste Materials' by R. M. FINCH, O.B.E., M.I.C.E.

The text of the six lectures, together with that of the First Graham Clark Lecture delivered by Sir Harold Hartley in 1955, will be published later in book form.

THE INSTITUTE OF RADIO ENGINEERS

Members who subscribe to the *Proceedings of the I.R.E.* are asked to note that the annual subscription rate has been increased as from the 1st October 1956 to $13.50 (£4 17s. 6d.).

THE INSTITUTION OF POST OFFICE ELECTRICAL ENGINEERS

At the Jubilee Meeting of The Institution of Post Office Electrical Engineers, which was held at Savoy Place on the 8th October 1956, Sir Gordon Radley conveyed the congratulations of the Council of The Institution of Electrical Engineers to members of the Post Office Institution.

UTILIZATION SECTION

MEETING ON THE 17TH JANUARY 1957

The following paper will be read and discussed at the meeting of the Utilization Section on the 17th January 1957: 'Electricity in Modern Commercial Horticulture' by C. A. CAMERON BROWN, B.SC., and A. W. GRAY.

ANNUAL DINNER-DANCE

As previously announced, the Annual Dinner-Dance of the Utilization Section will be held on the 16th January 1957 at the Café Royal, Regent Street, W.1. Details and application forms are being sent with this issue to all members of the Section.

CLEAN AIR

The Clean Air Act is now on the Statute Book, and with the idea of stimulating discussion on the whole subject The Institution of Mechanical Engineers is organizing a conference on 'The Mechanical Engineer's Contribution to Clean Air'. The conference will be held in the Central Hall, Westminster, and members of our Institution are invited. It will start on the evening of the 19th February 1957, when Sir Ewart Smith will give the opening lecture, and the technical sessions will occupy the next two full days. The registration fee of £1 5s. will include a complete set of advance copies of the papers and buffet refreshments on the opening evening. Further details and registration forms may be obtained from the Secretary, The Institution of Mechanical Engineers, 1 Birdcage Walk, Westminster, London, S.W.1.

IRON CASTINGS IN ENGINEERING

BRITISH CAST IRON RESEARCH ASSOCIATION

A conference on 'The Engineering Properties and Uses of Iron Castings', organized by the British Cast Iron Research Association, is to be held from the 28th to the 30th November 1956 in the Connaught Rooms, Great Queen Street, Kingsway, London.

The purpose of the conference is to consider the uses and behaviour of cast iron in various fields of engineering and the suitability of the material under given conditions of load and stress, wear and corrosion.

The attendance fee is £2. Further details may be obtained from the Manager, Intelligence Department, The British Cast Iron Research Association, Bordesley Hall, Alvechurch, Birmingham.

HOME EVENTS

LEEDS

NORTH MIDLAND CENTRE

Our new session opened on the 2nd October 1956, when our retiring Chairman, Mr. F. Barrell, before 120 members, presented the Baillie Memorial Prize to Mr. H. J. Towse, immediate Past-Chairman of the Graduate and Student Section, for his paper *Traction Control Gear Design*. Then, after welcoming two new Corporate Members, he called on the incoming Chairman, Mr. W. K. Fleming, to deliver his Inaugural Address, entitled *Electricity Supply and the Public*. We found Mr. Fleming's discourse to be a most interesting one, dealing as it did with the historical development of the electrical supply industry and with all the complex considerations of public relations which are involved in this industry. Mr. F. W. Fletcher, in expressing our thanks to Mr. Fleming, said that he was particularly interested in the section dealing with relationships between employee and consumer, which contained many passages worthy of meditation. Mr. G. Caton, seconding, dwelt upon the sincerity of the Address and the manner of delivery, and commented amusingly on the feelings of relief which must now be flowing over Mr. Fleming after a job well done.

In the unavoidable absence of Mr. J. R. Rylands, Mr. J. G. Craven kindly made the appeal for the Benevolent Fund, and the amount collected was over £17. Mr. Barrell then invited Mr. Fleming to occupy the chair, and Mr. A. J. Coveney thanked Mr. Barrell for all the drive, energy and enthusiasm which he used for our benefit during his year of office. Mr. J. D. Nicholson seconded, saying that Mr. Barrell was an 'engineer plus', that he used all he had in every project which he took up, and that we had been well and truly served. Our new Chairman then presented to Mr. Barrell a copy of *The History of The Institution* together with the Certificate of Chairmanship. In reply Mr. Barrell said that his year of office was a great honour to him, that he had been ably and loyally supported by the Honorary Secretary and the committee, and he spoke of the pleasure which the inauguration of the Catterick District Meetings had given him.

Graduate and Student Section. The Annual Joint Dance of Graduates and Students of the three Institutions will be held on the 14th December 1956, at the new staff refectory, Leeds University, from 8 p.m. to 1 a.m. There will be a bar and a running buffet. A specially hearty invitation is extended to all senior members and their friends to attend this function. Tickets, price 7s. 6d., may be obtained from Mr. E. G. Hopper, Danefield House, Leeds Road, Otley. J. L.

READING

DISTRICT MEETING

Oil for Insulation

Mr. R. B. Brown presided at the first meeting of the new session on the 1st October 1956, when twenty-four members and guests heard a talk by Mr. C. F. McCue on *Insulating Oils for the Electrical Industry*. The talk was illustrated by the showing of a film.

After briefly describing the various types of hydrocarbon in petroleum, Mr. McCue reviewed the characteristics required in the different oils used in the electrical industry and the methods employed to obtain them.

Transformer oils must not only be good electrical insulators and heat dissipaters; they must be able to withstand temperatures below 30° C without solidifying and above 70° C for many years without developing sludge or acidity. At the same time they must not be too volatile or inflammable. These properties are achieved by cutting a suitable fraction from a selected crude oil and carefully refining it to a predetermined degree. Inhibitors may be added if exceptional stability is required. The same type of oil is often used in oil-immersed switches and capacitors, but special oils are necessary for capacitors in which the electrical stresses are very high, otherwise trouble due to gassing of the oil will occur. Gassing is also a problem in oil-filled (hollow-core) cables. The usual cure is to ensure that the oil contains a controlled amount of aromatic hydrocarbons, which absorb the liberated hydrogen and prevent it appearing as free gas. Various additives have been tried but none has been entirely successful.

An entirely different type of impregnant is required for solid-filled cables. This normally consists of a highly refined viscous oil to which has been added some form of thickener. Flash-distilled resin is the most common thickener for voltages up to 66 kV, but synthetic materials such as polyisobutylene are necessary for higher ratings.

The talk was followed by a discussion which covered a wide range of topics including passivated transformer oils, cable 'cheese', and the interfacial-tension test for assessing transformer oils in service.

This was one of the most attractive meetings held in the district, and the speaker was warmly thanked on behalf of the members by Mr. R. H. Abell. H. R. J. B.

Copyright: The Northern Whig, Ltd., Belfast

A photograph taken during the Supply Section summer visit to Northern Ireland in September this year, showing the Lord Mayor of Belfast greeting Mr. L. Drucquer, the Chairman of the Section for 1955–56. With them are Major E. N. Cunliffe, Mr. D. M. G. Newburn and Mr. J. N. Ratcliffe. An account of the visit will appear in next month's Journal.

SCOTLAND

SCOTTISH CENTRE

Increasing Humidity in Glasgow

At the end of last session it was decided that the Chairman of the Scottish Centre should deliver his Chairman's address at the first meeting of each Sub-Centre instead of later in the session as hitherto. Accordingly Professor F. M. Bruce delivered his address in Edinburgh on the 2nd October, in Glasgow on the 3rd, in Aberdeen on the 10th and in Dundee on the 11th. The formal inauguration of the new Chairman, and the presentation to the retiring chairman, Dr. E. Wilkinson, of his certificate of office and a copy of *The History of The Institution*, took place at the Glasgow meeting, this being the meeting of the Sub-Centre of which the new Chairman is a member.

Professor Bruce spoke on post-graduate research with particular reference to the work being done in the electrical engineering department of the Royal College of Science and Technology, Glasgow. This work chiefly concerns high-voltage discharges in uniform electric fields and investigations into the establishment of the follow-current that succeeds an initial breakdown in a live power circuit. Professor Bruce described the basic theory underlying the development of the arc and spark, and illustrated his talk by many unique photographs of discharges. Among the equipment described were special circuits for providing follow-currents, and a proposed testing chamber in which humidity can be varied over an even wider range than that normally available in Glasgow. Though the work described was largely fundamental research, it has important practical applications, and the formal request that Professor Bruce permit it to be published in the *Proceedings* was very warmly supported. E. O. T.

NEWS *from Abroad*

BRISBANE

QUEENSLAND SECRETARIAT

On the evening of the 24th August 1956 a combined meeting was held with the Institution of Engineers, Australia, to hear a paper by Mr. J. E. Morwood, entitled *Tennyson Power Station, Brisbane*. Mr. Morwood is the Chief Engineer and Manager of the Electricity Department of the Brisbane City Council and has been closely associated with the Tennyson project since its beginning.

As this meeting had been organized by the Australian Institution, it was under the control of the Chairman of their Brisbane Division, but in recognition of the close association between it and The Institution, proceedings were opened by Mr. A. S. Faulkner, Chairman of the Queensland Oversea Committee, who then handed over to Mr. E. M. Shepherd. On this occasion we were fortunate in having present Mr. R. W. J. Mackay, President of the Institution of Engineers, Australia, who was making a brief visit to Queensland.

In introducing his paper, Mr. Morwood gave a short résumé of the history of generation of electricity in Southern Queensland and of the selection of the site for the Tennyson power station. The body of the paper gave an outline of the planning of the location, design, layout and equipment of the station and showed that adequate provision had been made for growth over a considerable period. At present two 30 MW sets have been installed and there is room on the site for a further four such sets, or for two rated at 60 MW. The lecture was abundantly illustrated with lantern slides, those in colour being very attractive.

In moving a vote of thanks to the speaker, Mr. J. S. Just reminded the audience that the Tennyson scheme was one very dear to Mr. Morwood, and offered congratulations on the progress that had been achieved. W. I. G.

NIGERIA

WEST AFRICA JOINT OVERSEA GROUP

Twenty-five members attended the third Annual General Meeting of the Group on the 11th May 1956. A new Committee was elected with Mr. R. Bridgman, M.I.C.E., as Chairman and Mr. R. E. J. White, A.M.I.MECH.E., as Hon. Secretary. The incoming Chairman delivered his Inaugural Address on *The Development of Freight Transport in Nigeria.*

The second conversazione, held on the 29th June, was a very successful function, at which 130 members and guests were present. After a buffet supper films were shown, including, as the principal item, *The Ascent of Everest.*

A goodwill visit was paid to the Gold Coast Branch of the Group on the 19th and 20th July by the Chairman and Honorary Secretary. A tour of engineering works was made which included the new quarry at Shai Hills and the harbour works at Tema. During the evening Mr. Bridgman presented his paper on *The Comparative Cost of Road and Rail Transport in Nigeria.* On the following day the party travelled to the Volta River to inspect the arch suspension bridge which is under construction.

During a film evening on the 24th August, attended by sixty-eight members and guests, a presentation was made to Mr. R. G. M. Bathgate, A.M.I.C.E., in recognition of his exceptional services to the Group as Hon. Secretary from 1954 to 1956, and the Graduate's Prize was presented to Mr. R. E. J. White, A.M.I.MECH.E., for his paper entitled *Some Notes on the Industrial Gas Turbine.*

Two new Branches of the Group have been formed in the northern and eastern regions of Nigeria. The headquarters of the former is at Kaduna, with Mr. H. P. Pooley, M.I.C.E., as Chairman and Mr. J. Meade, A.M.I.E.E., as Hon. Secretary. The latter is centred on Enugu, with Mr. W. D. B. Kingston, M.I.C.E., as Chairman and Mr. H. T. Astley, A.M.I.C.E., as Hon. Secretary. R. E. J. W.

OVERSEA ATTENDANCE REGISTER

During the period 1st September to 30th September 1956 the following members called at the Institution Building and signed the Attendance Register of Oversea Members:

ASCHNER, F., DR.ING., DIPL.ING. (Haifa).
BARROW, R. G. (Seria, British North Borneo).
BOWKER, H. C., B.SC.(ENG.), PH.D. (Calcutta).
CHAKKO, J. M. (Bombay).
CROWE, J. P. (Sydney).
FLANDERS, R. D. (Nicosia).
GHOSH, C. S. (Bangalore).
HAYWARD, P. C., B.E., B.SC. (Sydney).
KATZELIS, N. G. (Nicosia).
KRISHNAN, V. (Bangalore).
NG, K. Y., B.SC.(ENG.) (Ipoh).
RAMAMRITHAM, V. (Calcutta).
SKERREY, C. E. (Basrah).
SMITH, C. R. N. (Tremp, Spain).
TALBOT-JONES, R. V. (Nairobi).
WALMSLEY, F. R. (Lagos).
WESTCOTT, N. (Johannesburg).
WONG, K. H., B.E.E. (Kuala Lumpur)
ZANOBETTI, Professor D., DR.ING. (Bologna).

Elections and Transfers

The following elections and transfers approved by the Council are effective from the 1st September 1956.

ELECTIONS

Associate Members

CRESSELL, Archie George Ian, B.SC.
DAVIES, Granville.
DE SOIGNIE, Edouard.
DUCKWORTH, Capt. Ralph Campbell Musbury, C.B.E., R.N.
EBBESEN, Aksel, M.SC.
EDNEY, Brig. Alfred John, C.B.E.
GASTON, John, B.SC.
HASLETT, Roy William George, B.SC.
HETHERINGTON, Frank.
HEYWOOD, John Chadwick, B.SC.
HUGHES, Hugh.
JEWSBURY, Sydney, B.SC.
MILLAR, Bryan, B.A.
MILLAR, Robert Neil, M.A., B.COM.
MONKHOUSE, Francis Brown.
PRIOR, Charles Acton Morris, B.SC. (ENG.).
SIVERS, Carl Henric Von.

Associates

AITKEN, Peter.
BREWER, Douglas Eric.
COOPER, Geoffrey George John.
DAVIES, Edwin Ronald.
DOUGLAS, Norman Cairncross.
EMMETT, Leonard Leslie.
GRIFFITHS, John Noel Bruton.
HANCOCK, Eric Alfred J.
HARRISON, Eric Graff.
JACKSON, Edward William.
LANCASTER, William Marshall.
THOMSON, Andrew Bernard.
WALSHA, John Ernest Frederick.

TRANSFERS

Associate Member to Member

AUSTIN, Major Donald Relton.
AXWORTHY, Francis Roy.
BENNETT, James.
BLUE, James Lamont.
BURDICK, Robert Harry.
EAGLING, Olaf Alfred.
EMERSON, Samuel James, M.ENG.
FARRALL, Terence, B.SC.(ENG.).
FELTON, Alonzo, B.SC.(ENG.).
FRENCH, Ronald Richard.
HARDIE, Alexander Merrie, M.A., B.SC.(ENG.).
HODGSON, Kenneth George, B.A.
JAMES, John Frederick, B.SC.
MARSHALL, Joseph Ernest, M.ENG.
NEILL, Major Stanley Francis Mundy.
NICHOLSON, George Galloway, M.ENG.
NUTTALL, Harold.
PATEL, Shivabhai Purushottamdas, B.E., B.SC.
PINOFF, Frederick Morris.
RENTON, Robert Norman.
ROSS, Douglas Graham.
ROWLEY, Basil George Harold, M.A.
SHIVRAM, Tiruvottiyur Muniswami.
SKIPSEY, Joseph Fendley, B.SC.
THWAITES, George Percy, B.SC. (ENG.).

Associate to Member

GREEN, Ernest, M.SC.

Associate to Associate Member

AINSWORTH, Edward James.
HULCOOP, George John.

Graduate to Associate Member

APPLEBY, John Stanley, B.SC.(ENG.).
APSIMON, Walter Idris.
BARCLAY, John McBride.
BATEMAN, Derek Walter.
BATTLEY, Francis George.
BEAVEN, Donald Arthur.
BEDSON, Charles Joseph, B.SC.(ENG.).
BESHAW, Eric George.
BIKKER, Anthony.
BLAIR, David John.
BOLD, Peter Bucknall.
BROWN, William Mackie, B.SC.
BURNHAM, Peter Douglas.
CARROLL, John Walter, B.SC.(ENG.).
CHEONG, Siew Keong, B.SC.(ENG.).
COLLINS, Dermot Joseph, B.SC.(ENG.).
COLLINS, Michael Henry Francis.
DAVIS, John Charles Basil.
DAVIS, Patrick Goronwy, M.SC.
EDGAR, Anthony Kennedy, B.SC.
FORD, Philip Anthony.
FOZDAR, Jamshed Khodadad, M.S.
GIBSON, Arthur.
GILES, David Stuart, B.SC.(ENG.).
GRAHAM, Alfred James, B.SC.
HANKINS, William Corbett.
HEYS, Thomas Eric.
HILL, Derek James.
HIORNS, Derek Spencer, B.SC.(ENG.).
HIRST, Capt. Raymond, R.E.M.E.
HOCKLEY, Henry James Morrill.
JOHN, Robert.
JOHNSTON, David Raymond.
JONES, John Tudor.
JONES, Lt.-Cmdr. John William Ewart, B.A., R.N.
JONES, Philip Thomas.
KAR, Trilokinath, B.SC.(ENG.).
KEILLER, Charles.
LAIDLER, Roy.
LEHMANN, Manfred, B.SC.
LIBBY, John Eric, B.SC.
LUSCOMBE, Edward William, B.SC. (ENG.).
MATHER, John Gavin, B.SC.(ENG.).
MATTHEWS, Capt. Norman Denis, R.E.M.E.
MILNE, James Fyffe.
NICHOLAS, Herbert Kenneth.
READ, Edward James.
REY, Noel, B.SC.(ENG.).
ROBERTSON, Iain Wylie.
ROSIER, John Sidney Joseph.
ROTSTEIN, Hermann Leon, B.SC.
SANSOM, Kenneth Harold.
SHOWELL, Herbert Alfred.
SLOAN, Ronald William Eric, B.SC.
SMITH, Arthur Leonard.
STALLARD, Reginald Albert.
STANIER, Harold Meredith, M.A., PH.D.
TAGG, John Roger, B.SC.(ENG.).
TULLY, George Brian, B.SC.
UMRIGAR, Dhanjisha Manekji.
VON KEISENBERG, Ernest Marshall, B.SC.
WATERS, Roy Frederick George.
WHITTLE, Gordon Moffatt.
WILLIAMS, Ewart George.
WILLIAMS, Maldwyn, B.SC.
WILSON, Sydney, B.SC.
WINTER, Frederick Edwin Charles.
WOODING, Patrick John, B.SC.(ENG.).
WORTH, Desmond Frederick Joseph, B.SC.(ENG.).
YOUNG, Eric.

Student to Associate Member

KING, Frank Edward Hockedy, B.SC.
WARBY, Richard John.

The following elections and transfers approved by the Council are effective from the 13th September 1956.

ELECTIONS: 1st LIST

Graduates

ATKINSON, Derek John.
BAYLISS, Trevor William.
BHAGWAT, Purushottama Ramchandra, B.SC.
BLACK, William Stewart.
BLATCHER, Ronald Charles.
BLELLOCH, Robert Andrew, B.A.
BOOTH, George Arthur.
BRADLEY, Roy.
BROCKELSBY, William Keith, B.E.
BROWN, Michael Dunster.
BURGE, Stanley Albert.
CEARNS, Clarence Malcolm Douglas, B.E.
CHAN, Yang Pun.
CLYNE, John Peter, B.A.
COLE, Richard Stanley Linter, B.SC.
COWAN, Robert.
CURTIS, Edward.
DAVIS, Timothy John Archer, B.SC. (ENG.).
DINN, Michael John, B.SC.(ENG.).
DREW, Ronald John.
DUNLOP, Alastair Donald.
EMMETT, Brian Frederick, B.SC.
EWINGTON, Harold.
GHOSH, Ranajit, B.E.E.
GRAYSTONE, Peter.
GREGORY, Robert.
HALL, David John, B.SC.(ENG.).
HALL, David Peter.
HAMER, John Stanley.
HARROD, Roy.
HEFFORD, Peter George.
HOARE, Douglas John.
HODGSON, John.
HOLDSTOCK, Robert Alfred.
HOLLOWAY, Philip Lindsay.
JONES, Ian Clifford, B.SC.(ENG.).
KELLY, Peter Joseph.
KELLY, Stanley Raymond, B.SC. (ENG.).
KIRKDALE, Anthony Piero, B.SC. (ENG.).
KNOWLES, Harry.
LEE, Edward Stewart Edmund.
LEONARD, Raymond.
LIMAYE, Shripad Keshav.
LOVELACE, Trevor Arthur.
McGREGOR, Edwin Herbert.
McNEILL, Norman James, B.E.E.
MAYHALL, John Gerald.
MEAD, Lionel Charles.
MILLAR, Ormond Douglas.
NASH, Ronald.
PANICKER, Attakuzhikkattu Ramaa Sreedhara.
PARKES, Jack.
POOLER, William John Robert Hollies, B.A.
POUNTNEY, Joseph Thomas.
PTAK, Aleksander, B.SC.(ENG.).
REID, Thomas.
RIDDLE, Eric Raymond, B.SC.
ROSS, Gordon McKenzie, B.E.
ROSS-GOWER, Edward Lewis.
ROXBURGH, John Thomas.
RUSS, Ronald Frank.
SHRUBSOLE, Ivor Albert.
SMALL, George Edgar.
SMITH, George Bernard.
SMITH, Joseph Colin.
SNELL, James Lawrence.
SPELLER, Reginald Harry.
SZCZYGIEL, Jan Zdzislaw.
TRELINSKI, Jerzy Antoni, B.SC. (ENG.).
TRIMMER, Ronald Keith Lewis.
UNDERDOWN, Dennis Cyril.
WAGGOTT, John Telford.
WAKEFIELD, Maurice William.
WILLS, Aldwin Edward.
WINFIELD, Sidney Kenneth.
YARDLEY, John William.
ZAMBARDINO, Rodolfo Alfredo Giacomo, DOTT.ING.

Students

ASHRAF, Khawaja Muhammad, B.SC.
BADRINATH, Erode Ramaswami, B.SC., B.E.
BAILEY, William Dalziel.
BEADLE, Ronald Edward.
BEAUMONT, Jack.
BEEBY, Peter Daniel.
BRISTON, Michael Harold.
BUICK, Frederick John, B.SC.
BURDES, John Proom.
CARMICHAEL, Neil Carswell.
CHEBI, Paul, B.SC.
CHEESEMAN, David Edwin.
CORKREY, Thomas Edward Lawrence.
DAVIDSON, James Smyth.
DAVIS, Bernhard.
DUCKER, Francis Ronald.
ENGLAND, John Terence.
FAWCETT, Brian Jack.
GASKELL, Colin Simister.
HARVEY, Anthony Thomas.
HICKLING, Brian George.
HOGG, James Pitcairn.
JAIN, Madan Gopal.
JEFFCOTT, Leslie.
JENKINS, David, B.E.
KHOR, Michael Teik Hean.
KIRK, David William.
LOSA, Emmanuel Efue.
McCLEAN, Robert.
MASKREY, Joseph Norman.
MEHTA, Darayes Bahadur, B.E.
MILLEN, Royston James.
MIRZA, Mohammad Akhar.
MOHIDEEN, Mohamed Junaid.
MORLING, Kenneth Frank.
MORRIS, Selwyn James.
NICHOLLS, Ian George.
NICHOLLS, Keith David.
ORR, Graeme Alexander.
PAINTER, Michael John.
PAIS, Joseph Cyril.
PARKER, Douglas Albert.
PAYNE, David Malcolm.
ROACH, Maurice Leslie.
SCRIVEN, John.
SMITH, Colin Sidney Albert.

Students (contd.)

STILES, Lionel Lawrence.
SUBBANNA, Nittur Sreenivasarau, B.E.
TEARLE, David Thomas.
THOMPSON, Ernest Kenneth.
TILFORD, Anthony Kenneth Graham.
TRACEY, Peter Martin.
TURNER, Graham Kelcey.
VAN RENSBURG, George William.
VELTMAN, Frederik.
WALDRON, Dennis Alfred, B.SC.
WALKER, Ronald.
WILLDEY, Geoffrey Michael, B.SC.

TRANSFERS: 1st LIST

Student to Graduate

ALECOCK, Grahame John, B.E.
ATKINSON, John Robert.
BALMER, Peter, B.SC.
BARKER, Cecil Colin, B.SC.TECH.
BHAGOWALIA, Balbir Singh, B.SC.
BISWAS, Parames, B.E.E.
BORLAND, Miss Margaret Christine Jessie, B.SC.
BUNZL, Thomas Felice.
BURDETT, David Lionel.
CARDWELL, Thomas Cuthbert, B.SC. (ENG.).
COOK, Robert Alfred.
COTTERILL, Roy.
DAS GUPTA, Asit Kumar, B.SC.
DEARNLEY, John Dean, B.SC.
EVANS, John Garvin, B.SC.(ENG.).
GEARY, Ronald, B.SC.
GEORGE, Roger Geoffrey, B.SC. (ENG.).
HILL, Michael Walter.
HOPE, Richard Arthur.
KENT, Alan Hugh, B.SC.(ENG.).
McALPINE, Thomas, B.SC.
McCARROLL, Eric.
MATTHEWS, Peter Ash, B.SC.(ENG.).
MOLES, Robert George Holland, B.SC. (ENG.).
MOORE, David Henry, B.ENG.
MOORE, Edwin Royston.
NICOL, Robert William.
NORSWORTHY, Keith Harvey, B.SC.
OKEKE, Richard Nwachukwu.
PITCHES, Roy Edwin.
RANGANI, Dwarka Hundraj Sada.
SALTER, Michael John, B.SC.(ENG.).
SCOTT, Donald Arnold.
SMITH, Norman, B.SC.
SOPPET, Douglas Athol.
SPENCE, Robert, B.SC.(ENG.).
STOBIE, John, B.SC.
SUMMERS, Edgar Charles, B.SC. (ENG.).
TALUKDER, Banajit Kumar, M.SC.TECH.
THORNTON, Douglas John, B.A.
TURL, Alan Francis, B.SC.(ENG.).
TYERS, Anthony, B.SC.
WAGSTAFF, Maurice, B.SC.TECH.
WALFISZ, George.
WILKINSON, George Ian.
WILSON, Brian, B.SC.(ENG.).

ELECTIONS: 2nd LIST

Graduates

ABEL, Eric David.
ABRAHAM, Jacob.
ADIBI, Mahmood, B.SC.
AL-IMMAM, Hussain, B.SC.
ANDERSON, Sidney Thomas.
BAI, Douglas William.
BANKS, Colin.
BARFORD, William.
BEANLAND, Charles John.
BEDDOE, Brian, B.SC.
BELL, Ronald Inch.
BHARGAVA, Suresh Chandra, B.SC. (ENG.).
BISHOP, John Henry George.
BLACKHURST, Albert William.
BOYLE, Daniel.
BRYANT, Peter, B.SC.(ENG.).
BUNKER, Hedley John.
BURNETT-JONES, William, B.E.
CHATBURN, James Henry.
CHILTON, Alan.
CLARKE, Norman.
CONANT, Charles Richard, B.SC. (ENG.).
COOKE, Raymond John, B.SC.
COOPER, Colin Bayliss, B.SC.
COX, Peter John, B.SC.
CZACZKA, Adam.
DAS, Nirmalya Bhushan, M.SC.
DASS, Bhagyadhar, B.SC.
DATTA, Sankaracharyya, B.SC., B.E.E.
DAVIS, Leonard William.
DEAL, Alan William.
DEAS, William.
DEBRAH, Peter Tetteh.
DEELEY, Edward Mountford, B.SC., PH.D.
DOWNING, Stuart Alan.
DULEY, Anthony John.
EDWARDS, Lawrence Bond.
FARGHALY, Alam El-Din Sayed, B.SC., PH.D.
FARR, David Nairn, B.A.
FARROKHZAD, Firooz, B.SC.
FRANKLIN, George Samuel.
FRANKLIN, Peter James.
FROST, Dudley John.
GARNER, Frederick, B.SC.(ENG.).
GEROLEMOUS, George.
GIBSON, John Kenneth, B.SC.
GIDWANI, Moti Hashmatrai.
GODSAVE, Alan Francis.
GREAVES, Robert Stuart.
GREENALL, Herbert Alexander Martin, B.SC.
GRIGGS, Frederick John Martin.
GRIMA, Joseph Francis.
HARDING, Derek William, B.SC.
HARIHARA IYER, Srinivasa, M.SC.
HARLAND, Capt. Denis John Stuart, R.E.
HAVINDEN, Clifford Leonard.
HAZELL, Kenneth George.
HENRY, Wilfred.
HLAING, Sein, B.SC.(ENG.), S.M.
JONES, John Bryan Adpar.
JOYCE, Norman John.
KAIGHIN, John William Fife, B.SC.
KAUL, Pran Nath, B.SC.
KEAR, John Ernest.
KERSS, William.
KUREISHY, Izhar Uddin, B.SC.
LIGHT, Ian Herbert, B.SC.
McCARTHY, Roy Keith.
McCORMICK, Charles William Diehl, B.ENG.
McGENNIS, Edward Anthony, B.E., B.SC.
McWHINNIE, Colin David.
MAGSON, Derrick Edward.
MAHARATNAM, Muttaiah.
MASON, Albert Charles.
MAYOH, Eric.
MILES, Peter Arthur.
MILLER, John Tennant.
MORRIS, Dennis William.
OLIVEY, Lt. Albert William John, R.N.
OXFORD, Derek Frank, B.SC.
PERRY, Ronald Charles.
POPE, Roger, B.A.
POWELL, Charles William.
RABBETTS, Rodney Ernest John.
RAMA IYER, Padmanabha, B.SC.
RAYMENT, Frank William.
READ, Stanley James, B.SC.(ENG.).

Graduates (contd.)

RENTON, Alexander.
ROGERS, Alan Edwin, M.A.
ROSS, Wilson.
RUSSELL, Denis Herbert.
SARIN, Sat Pal, B.SC.
SCED, Malcolm Stephen.
SELVANANTHAM, Sinnappu Elijah Richard.
SHACKSHAFT, Geoffrey, B.ENG.
SHARP, Peter.
SHERRARD, Eric Ingram, B.SC.
SHIVRAM, Ramchandra, B.E.
SIMS, Jack Thomas.
SMITH, Brian Richard, B.SC.(ENG.).
SMITH, Gordon Arthur, B.SC.
SMITH, Terence David.
SPENCE, Norman Jeremiah.
STEWART, Noel Patrick Cheyne, M.A.
STIRLING, John Mowat Miller, B.SC.
STOCKDALE, Harry.
SULLIVAN, Ronald John.
TAMARIS, Alan Leslie, B.SC.
TAYLOR, Samuel.
TEESDALE, Reginald Roy, B.SC.
THARMALINGAM, Kandiah, B.A., B.SC.
THOMAS, James Geoffrey, B.SC.(ENG.).
THOMPSON, Austin Rex, B.SC.
TROMAN, Donald.
TUCKER, Reginald James Walter.
TURNER, Peter Allan.
WADHAWAN, Krishan Lal.
WAGSTAFF, Brian Buchanan, B.SC. (ENG.).
WARRIOR, Keerankulangare Viswanath.
WATERTON, Barry Albert Russell.
WEATHERLEY, Harold.
WIGGANS, Peter Robson, B.SC.
WILLIAMS, Geoffrey William.

Students

ADELSKY, Benjamin Joseph.
ARCHENHOLD, Wolfgang Friedrich.
ARNOLD, Vaughan.
ASHTON, Derek Cyril.
BASS, Patrick Leon.
BONNERJEE, Nityananda.
BOOL, Christopher John.
BROWN, Graeme Malcolm.
BULL, John Trevor.
BYRNE, Laurence Patrick Christopher.
CHAKI, Pradip Kumar, B.E.
CHESTERMAN, John Hurrell.
COZENS, David Sydney.
CROSS, Peter James.
DE SILVA, Marakkalage Francis.
DOYLE, Michael Francis.
DUNSTAN, David Sydney.
EDWARDS, Ronald James, B.SC.
ELLIOTT, John Richard.
ELLIOTT, Robert Lennox.
FERBER, John Frederick.
GHANI, Feroz, B.SC.
GORE, Bohdan Theophilus Nicholas.
GRAY, George William Peter.
GRIERSON, David William.
GULVIN, Thomas Frederick, B.SC.
HAMMAN, Michael Herbert.
HANSCOMB, Anthony John.
HART, David Benjamin.
KARUNATILLEKE, Hemasiri Dias Silva.
KELLY, Peter John, B.SC.
KERSLAKE, Kenneth William, B.SC.
KILN, Peter Graham.
KORVINK, Gerrit Jorgen.
LEWIS, Richard Norman.
LYTTON-ANDERSON, Sean Stuart-Desmond.
MacINTYRE, Gilbert Roy.
MALBY, Alan Ronald.
MASSEY, George.
MILLNER, Brian Richard.
O'BRIEN, Kevin Michael.
PHILLIPS, James Douglas.
RADFORD, Anthony Joseph.
RAMANATHAN, Thambapillai.
RANASINGHE, Sydney Aloysius.
SENGUPTA, Prasanta Kumar, M.SC.
SHERIFF, Desmond Aubrey.
SOAMES, Spencer Thomas.
THARMALINGAM, Sinnappu.
THOMAS, Leslie.
VARMA, Ram Parkash, B.A.
WEERASURIYA, Neil Sumitra Warnakula.
WEGNER, Peter, B.SC.
YOUNGS, Fountain Charles Lockwood.

TRANSFERS: 2nd LIST

Student to Graduate

ALAZRAKI, Albert, B.SC.(ENG.).
ALLAN, William James Wilson.
ARBAB, Aftab Ahmad.
ASHTON, Carrick Holford W.
ASTWOOD, Stewart Alexander.
BAMBURY, Bartholomew.
BANERJEE, Rangalal.
BARRETT, Frederick Critchlow.
BAXTER, Ronald Scott, B.SC.
BELL, William David.
BLADES, Michael William.
BOWER, Leslie George
BRIDGMAN, Arthur Henry Stuart, B.SC.(ENG.).
BROWN, Michael Alexander.
CAIRD, John Aitchison.
CAMPBELL, John George Govan.
CAWDERY, Anthony Devereux, B.SC.
CETNAROWICZ, Zygmunt.
CHANDRA, Dinesh.
CHATTERJEE, Dilip Kumar, B.SC., B.SC.(ENG.).
CHOPRA, Pal, B.SC., B.SC.(ENG.).
CLEMENTS, Robert Augustus, M.SC.
CORNWALL, John Bevin.
CREASY, Nigel Irving, B.SC.(ENG.).
CRIDGE, Lance Neville.
DAS, Brahmajosyula Vira Raghava.
DAVIDSON, Angus James Sommerville, B.SC.
DEVARHUBLI, Vasudeo Balkrishna, M.SC.
DEVERICK, Eric Irvine.
DHILLON, C. I. O. Kripal Singh, I.N.
EDWARDS, Alan.
EFTHYMIADIS, Athanasios, B.SC.
FINLAYSON, George Scott.
FONG, William.
FRENCH, Brian Arthur George, B.SC. (ENG.).
FROGLEY, Ian Alexander.
FROST, Evan David, B.A.
GALLAGER, Peter.
GILL, Rajinder Singh.
GLEAVE, Gordon.
GOLDHAMMER, Arthur Brian, B.E.
GORRINGE, Ronald Harold, B.SC. (ENG.).
HALL, Allen, B.SC.
HANCOCK, Raymond Geoffrey, B.SC. (ENG.).
HARBIDGE, Leslie William.
HARGROVE, Harold Johnathan.
HASHIM, Agha H., M.SC.
HEALD, Wyndham Holdane, B.SC.
HERBERT, Maurice Bryan.
HICKMAN, Peter John.
HILL, Robert Harry.
HOPE, Jack, B.SC.(ENG.).
HOVEY, Michael Albert.

Student to Graduate (contd.)

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JOHNSON, Joseph Frederick Campbell.
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KEAST, Capt. Barrie George, R.E.M.E.
KIDD, Derek Robert Tyldesley, B.SC.(ENG.).
KIMBER, Howard Frank.
KING, Melville John.
KNIGHT, David.
KURIATA, Tadeusz.
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LEVENS, Peter Philip.
LI, Seung Ping.
LLOYD, Brian Edmund.
McGRATH, Graham Albert.
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MARTINEZ-PEREZ, Pedro.
MILLER, John Alan, B.SC.
MINOCHA, Jit Lal.
MITCHELL, Nigel.
MITCHELL, Ross Eric.
MUNRO, Kenneth Neil.
MURUGESU, Somasundaram.
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NETHER, Ronald Egmont.
NUNNS, David.
PATTRICK, Brian Laughton.
PRAKASH, Prem, B.SC.(ENG.).
PRATTLEY, Winston Rayburn.
PRENTICE, Alan John.
PRESS, Graeme William.
PRESTON, Douglas Stuart George.
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RADHAKRISHNAN, Kodaikal.
RALPH, George.
RAMACHANDRAN, Venkatramaiyer.

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RILEY, Gordon Henry, B.SC.
ROPER, Roy Derek.
RYZLAK, Jan, B.SC.(ENG.).
SAMMONS, William Albert, B.SC.
SARKAR, Asim Kumar.
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SITARAM, Hadya Krishnaswamy, B.SC.
SKINNER, Peter.
SMITH, Everard John Edward.
SMITH, Ronald.
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STOREY, William Allan.
SURAWEERA, Piyasena.
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THAMBIRATNAM, Ratnasingham Emmanuel, B.SC.
THILLAILINGAM, Sanmugalingam.
TOLLEFSEN, Einar.
VANHEGAN, Robert Hope, B.SC.
WALKER, Frank Edgar.
WEBSTER, Ian George.
WEST, Nigel David, B.SC.(ENG.).
WHITAKER, Harry Brian.
WINTER, Kenneth Richard.
WOODFIELD, John Western, B.SC.(ENG.).
YIP IN TSOI, Tawat.
ZIMAN, Geoffrey Charles, B.SC.

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